# TEMPORAL PROCESSING AND SLUGGISH COGNITIVE TEMPO IN COLLEGE STUDENTS

A Thesis
by
ANNE ELIZABETH SORRELL

Submitted to the Graduate School
at Appalachian State University
in partial fulfillment of the requirements for the degree of
MASTER OF ARTS

May 2019
Department of Psychology

TEMPORAL PROCESSING AND SLUGGISH COGNITIVE TEMPO IN COLLEGE STUDENTS

A Thesis
by
ANNE ELIZABETH SORRELL
MAY 2018

APPROVED BY:

Will H. Canu, Ph.D.
Chairperson, Thesis Committee

Kurt D. Michael, Ph.D.
Member, Thesis Committee

Joshua J. Broman-Fulks, Ph.D.
Member, Thesis Committee

Rose Mary Webb, Ph.D.
Chairperson, Department of Psychology

Mike McKenzie, Ph.D.
Dean, Cratis D. Williams School of Graduate Studies

## Abstract


TEMPORAL PROCESSING AND SLUGGISH COGNITIVE TEMPO IN COLLEGE STUDENTS



Anne Elizabeth Sorrell
B.S., College of Charleston
M.A., Appalachian State University

Chairperson: Dr. Will H. Canu, Ph.D.



Sluggish cognitive tempo (SCT) was previously conceptualized in the literature as a cluster of symptoms related to the inattentiveness (IA) subtype of attention-deficit/hyperactivity disorder (ADHD). Recent evidence, however, has demonstrated that SCT is a distinct construct independent of, but often comorbid with, ADHD-IA. Still, findings regarding the neuropsychological nature of SCT are rather limited, particularly in comparison to ADHD. The aim of the current study is to add to the literature on SCT by examining the association between SCT and temporal processing abilities in a population of college-aged adults. Specifically, this study examines the associations between self-reported SCT symptom severity and time estimation/time reproduction abilities. Multiple linear regressions were conducted on seven dependent variables controlling for influence of ADHD. Results demonstrate that self-endorsement of SCT-related behavior may not significantly relate to performance on temporal processing tasks but do influence participants' self-reported of temporal processing abilities. Findings from this study will add

to extant literature on SCT and will help to establish its unique association with temporal processing abilities.

*Keywords* (3): sluggish cognitive tempo, adults, temporal processing

## Acknowledgments

First, I would like to express my sincere gratitude and appreciation to my thesis chairperson and graduate school mentor Dr. Will Canu for his guidance throughout this thesis project and my entire graduate studies. His enduring support, patience, and expertise have been crucial to my accomplishments at Appalachian State University. I would also like to express my sincere appreciation for the undergraduate research assistants in Dr. Canu's lab for the many hours they spent assisting me with this study. This could not have been completed without the help from each you. My sincere thanks also goes to the members of my thesis committee, Dr. Joshua Broman-Fulks and Dr. Kurt Michael, whose guidance and insights have been essential for this thesis completion as well as my personal development as a clinician and researcher. I would also like to thank all of the psychology faculty at Appalachian State University for providing an enriching graduate level education and further developing my passion for pursuing clinical psychology. Finally, I would like to thank my friends and family, especially my parents, John and Judy, and, of course, my dog Sallie, for their endless encouragement, support, and laughter these past three years. I love and appreciate you all so much!

## Dedication

I would like to dedicate this thesis to my English Springer Spaniel, Junior, who has been with me every step of this process. He is a genuine companion, and late nights and early mornings working on this project were made easier with him by my side. His loyalty and love have inspired me to be grateful for all things, big and small; his silliness has reminded me to appreciate the humor in life and that time for self-care, especially long walks in the park, are an essential part of every day.

## Table of Contents

## List of Tables

## **Foreward**

This thesis is written in accordance with the style of the *Publication Manual of the American Psychological Association (6th Edition)* as required by the Department of Psychology at Appalachian State University.

# Temporal Processing and Sluggish Cognitive Tempo in College Students

Anne Elizabeth Sorrell

Appalachian State University

Abstract

Sluggish cognitive tempo (SCT) was previously conceptualized in the literature as a cluster of symptoms related to the inattentive (IA) subtype of attention-deficit/hyperactivity disorder (ADHD). Recent evidence, however, has demonstrated that SCT is a distinct construct independent of, but often comorbid with, ADHD-IA. Still, findings regarding the cognitive underpinnings of SCT are rather limited, particularly in comparison to ADHD. The aim of the current study is to add to the literature on SCT by examining the association between SCT and temporal processing abilities in a population of college-aged adults. Specifically, this study examines the associations between self-reported SCT symptom severity, time estimation/time reproduction abilities, and other time management measures. Multiple linear regressions were conducted on seven dependent variables controlling for influence of ADHD. Results demonstrate that self-endorsement of SCT-related behavior may not substantially relate to performance on temporal processing tasks but does associate with participants' self-reported of temporal processing abilities. Findings from this study will add to extant literature on SCT and will help to establish its potential association with temporal processing abilities.

*Keywords* (3): sluggish cognitive tempo, adults, temporal processing

# Temporal Processing and Sluggish Cognitive Tempo in College Students

## Attention-Deficit/Hyperactivity Disorder and Sluggish Cognitive Tempo

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder with central behavioral characteristics of impulsivity, inattentiveness, and disorganization (American Psychiatric Association [APA], 2013). This disorder, which is commonly diagnosed in childhood, continues to contribute to psychological and functional impairment throughout adulthood. Three discrete presentations of ADHD with differing predominant symptoms have been identified: Predominantly inattentive (-IA), Predominantly hyperactive/impulsive (-HI), and Combined (-C; APA, 2013). In recent decades, a unique and putatively associated cluster of symptoms, termed Sluggish Cognitive Tempo (SCT), have become a focus in ADHD-related literature. Behavioral characteristics of SCT include excesses of the following: feeling sleepy or lethargic, having a tendency to daydream excessively, having trouble staying awake and alert, staring a lot, feeling mentally “foggy” or confused, seeming slow-moving or sluggish, and appearing to retrieve and process information slowly (Barkley, 2014). Though this cluster of behavioral symptoms appears similar to those of ADHD-IA, converging findings support that these SCT symptoms are indeed empirically distinct from ADHD-IA and perhaps should be considered as a separate disorder of attention (Becker & McBurnett, 2014; Becker et al., 2016).

Contemporary research on sluggish cognitive tempo dates to 1980, with the term likely being first-used in an article published by Lahey, Schaughency, Strauss and Frame in 1984 (Barkley, 2015). In 2001, Milich, Balentine, and Lynam published an influential literature review that reported study results comparing symptoms of ADHD and SCT (Barkley, 2015; Milich, Balentine, & Lynam, 2001). This review cited several studies (e.g., Carlson, & Niever, 1987; Carlson & Mann, 2002; Lahey et al., 1984; Lahey, Schaughency, Hynd, Lahey, Schaughency, Frame, & Strauss, 1985) that showed SCT formed a factor distinct from ADHD–IA and –HI presentation types. This finding sparked a surge of interest among those in the field, prompting researchers to identify characteristics unique to SCT.

Recently, several papers (e.g., Becker, Langberg, Luebbe, Dvorsky, & Flannery, 2014; Lee, Burns, Snell, & McBurnett, 2014; McBurnett, Villodas, Burns, Hinshaw, Beaulieu, & Pfiffner, 2014; Willcutt et al., 2014) examined the internal consistency of SCT using various methods, all finding that SCT represents a latent factor which is distinct from ADHD-IA. Other papers (Becker, Fite, Garnet, Greening, Stoppelbein, & Luebbe, 2013; Carlson & Mann, 2012; Lee, Burns, Beauchaine, & Becker, 2016) have found that individuals with SCT endorse more internalizing symptoms, such as anxiety and depression, as compared to peers with ADHD or Oppositional Defiant Disorder, who are more likely to exhibit comorbid externalizing behaviors. Research indicates that SCT and internalizing symptoms display moderate to strong significant associations, with SCT predicting depression and anxiety even when controlling for ADHD (Smith, Eadeh, Breaux, & Langberg, 2019). Additionally, recent literature has emerged giving support to the hypothesis that SCT is associated with emotion dysregulation (Flannery, Becker, & Luebbe, 2016b; Jarrett, Rapport, Rondon, & Becker, 2017) and poorer psychosocial outcomes in individuals with and without an ADHD diagnosis (Becker et al., 2014; Khadka, Burns, & Becker, 2015). In a sample of non-clinical, community adult participants, Combs and colleagues found that SCT predicted lower physical, psychological, and overall quality of life (Combs, Canu, Broman-Fulks, & Nieman, 2014), as well as higher levels of subjective stress (Combs, Canu, Broman-Fulks, Rocheleau, & Nieman, 2012), independent of ADHD. Specifically, SCT has been linked to deficits in overall energy level, capacity for work, ability to perform daily activities, sleep satisfaction (Combs et al., 2014), and self-organization (Barkley, 2012). Flannery, Luebbe, & Becker (2016) found that self-reported SCT symptoms in college students were significantly associated with impairment in social and work/education domains but not others, such as romantic relationships, sexual activities, driving, self-care, and daily organization and maintenance (Flannery, Luebbe, & Becker, 2016a). In a recent study of children, it was found that the social difficulties associated with SCT were primarily due to behaviors of withdrawal and isolation, as well as low initiative in social situations (Becker, Garner, Tamm, Antonini, & Epstein, 2017).

Limited research to date has sought to identify neuroanatomical differences in individuals with elevations in SCT-related behaviors. Fassbender, Krafft, & Schweitzer (2015) utilized functional magnetic resonance imaging (MRI) to investigate potential observable differences in the brain functioning of 29 adolescents with ADHD who did and did not have elevated SCT symptoms based on parental ratings. Most notably, their results revealed that individuals with elevations in SCT domains showed hypoactivity in the superior parietal lobe, suggesting impairment in the ability to reorient attention. This finding remained even when controlling for ADHD-IA. More recently, a study by Camprodon-Rosanas et al. (2019) examined associations between SCT symptoms and brain structure and function (specifically brain morphometry, white matter integrity, and functional connectivity in major neural networks) using MRI in 178 children from the population ranging from 8-12 years of age. Their findings suggest distinct anatomical and functional anomalies related to SCT, including a positive relationship between SCT symptom endorsement and increased regional volume in the frontal lobe, including the right prefrontal and premotor cortices. Importantly, these findings remained significant even after adjusting for ADHD symptom scores, suggesting that SCT-related behaviors are indeed related to distinctive features of brain structure and function that differ from the traditional neural substrates associated with ADHD (e.g., alterations in subcortical structures of the frontal-basal ganglia circuits). Though more neuroimaging research in this domain is needed, the results from the studies by Fassbender et al. (2015) and Camprodon-Rosanas et al. (2019) support the idea of a differentiation between SCT and ADHD-IA brain functioning symptom profiles. Future neuroimaging studies examining the neural substrates of SCT should recruit participants independent of an ADHD diagnosis in order to better compare the differences between the two disorders.

Given the positive correlations between SCT and internalizing disorders, as well as the perceived overlap in behaviors associated with each psychopathology, some have wondered whether SCT is simply a manifestation of underlying depression and/or anxiety. Results from several studies (e.g., Becker et al., 2018; Becker et al., 2014; Lee et al., 2014; Smith et al., 2019; Willcutt et al., 2014) demonstrate through confirmatory factor and multiple regression analyses that SCT represents a different, though related, dimension. Relatedly, because behavioral characteristics of SCT include drowsiness, lethargy, and daydreaming, it is not surprising that researchers have sought to identify the relationship between SCT and sleep, as well. In 2014, Becker, Luebbe, and Langberg published an article that evaluated the relation between symptoms of ADHD, SCT, and daytime sleepiness in samples of college students both with and without ADHD. Their factor analyses showed that, although related, SCT and daytime sleepiness are in fact empirically distinct. In both their clinical and non-clinical samples of students, SCT predicted daytime sleepiness above and beyond symptoms of ADHD, anxiety, and depression. Becker, Pfiffner, Stein, Burns, &

McBurnett (2016) confirmed these findings in a large clinical sample of children with ADHD-IA, most notably reporting that although SCT was significantly associated with parent reports of sleep functioning, the magnitude of correlations suggests that sleep and SCT are not redundant constructs. These findings have been replicated in additional studies examining the overlapping constructs of SCT, anxiety, depression, and daytime sleepiness (see Smith et al., 2019).

**SCT and Executive Functioning**

Of the many constructs that warrant further research in association with SCT, executive functioning (EF) abilities may be the most relevant, as deficits in these realms often correlate to impairment in daily life domains. EF is conceptualized in the literature as higher order cognitive abilities that facilitate goal-directed behavior and self-control (Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004). Specifically, EF abilities encompass skills such as behavioral regulation, working memory, organizational skills, self-monitoring, planning and implementing, cognitive flexibility, inhibitory control, self-awareness, vigilant attention, and set-shifting (Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009; Stuss & Alexander 2000). Due to the importance of EF across all life domains, and noted EF deficits in samples of those with ADHD (Geurts et al., 2004), recent literature has begun to investigate the relationship between these abilities and SCT, as well (Araujo-Jimenez, Jané-Ballabriga, Martin, Arrufat, & Giacobo, 2005; Bauermesiter, Martinez, & McBurnett, 2012; Flannery, Luebbe, & Becker, 2016; Tamm, Brenner, Bamberger, & Becker, 2016; Wood, Lewandowski, Lovett, & Antshel, 2017). Of the sparse literature published to date, the findings regarding how SCT relates to EF have been mixed and are summarized below.

As the name implies, processing information slowly is perhaps the most distinctive characteristic of SCT both in children and adults (Barkley, 2014). Differences in this ability tend to remain in those with elevated SCT even after controlling for ADHD and IQ (Willcutt et al., 2014). Given the behavioral characteristics of SCT (e.g., “slow,” “sluggish”), a relationship between SCT and slow processing speed is not unexpected. Speed of processing is particularly important as it is thought to have a direct impact on other higher-order mental processes (i.e., EF abilities) such as problem-solving, reasoning, and abstraction (Kail & Salthouse, 1994). As such, it is not surprising that studies examining the association between SCT and problem-solving abilities have also had consistent findings, with SCT demonstrated to be significantly associated with deficits in this cognitive domain (Leikauf & Solanto, 2016). Particularly in studies of adults, self-reports of SCT symptoms are strongly related to difficulties in the self-organizational/problem-solving domains (Jarrett et al., 2017) and account for more difficulties associated with self-organization and problem-solving than ADHD (Barkley, 2012).

Relatedly, the literature has appeared to agree that SCT may not be characterized by deficits in inhibitory control. Inhibitory control is the EF ability to exert self-control and inhibit, or purposefully resist, strong, automatic behavioral and/or attentional responses (Diamond, 2012), and is important in daily life activities. Deficits in inhibitory control (i.e., disinhibition) appear to be a central feature of ADHD. However, these deficits do not appear to be pervasive amongst individuals with SCT, especially when controlling for symptoms of ADHD-IA (Barkley, 2012; Wahlstedt & Bohlin, 2010; Willcutt et al., 2014). In their 2015 paper, Araujuo-Jimnez et al. explain that “perhaps the main difference between [ADHD-IA and SCT] symptomatologies is precisely the absence of behavioral disinhibition in SCT symptoms" (p. 512). The authors then note that although individuals with SCT may not have problems with inhibitory control, their ability to successfully inhibit may still be less-than-optimal given their impairments in other EF domains. Some researchers echo this notion, positing that instead of a lack of inhibitory control, SCT may be associated with difficulties in working memory and motivation (Barkley, 2012; Diamond, 2005). However, research is still inconclusive on the associations between working memory and SCT when controlling for ADHD-IA, particularly in the adult population (Tamm et al., 2016; Willcutt et al., 2014). The limited data and lack of consensus regarding the associations of SCT to EF elucidates the necessity of more research in these and other EF domains, as results could impact understanding of the disorder and predicate future treatment outcomes.

**Self- and informant-reports of EF abilities**. Generally, studies that use self- or informant-reported (e.g., parent or teacher) behavioral questionnaires assessing EF have found there to be distinct correlations with SCT. For example, in a study conducted by Becker and Langberg (2014), it was found that parent and teacher reports of SCT symptoms in children predicted metacognitive EF deficits (i.e., deficits in initiation, working memory, and task demands as assessed by the Metacognition scale on the Behavior Rating Inventory of Executive Function), even when controlling for ADHD. Relatedly, results from a study published by Jarrett et al. (2017) showed that self-reported measures of SCT were strongly associated with self-reported measures of EF (i.e., questionnaires), but not neuropsychological tests of EF. Actually, discrepancies between the associations of self-reported and neuropsychologically-measured EF abilities and SCT have been frequently reported in the literature. For example, Bauermeister et al. (2012) found in their study of Puerto Rican children that SCT is not associated with neuropsychological task measures of a limited number of EF constructs, such as working memory and problem-solving, but parent and teacher behavioral ratings of EF impairment and SCT *were* significantly associated. This and other studies (e.g., Becker & Langberg, 2014; Jarrett et al., 2017) demonstrate that SCT may be more associated with self- and informant-rated EF deficits that tap perceptions of functioning in daily life as compared to "laboratory-based tests of EF" (Bauermesiter et al., 2012; Becker & Langberg, 2013, p. 11).

Becker et al. (2017) point out that these differences between SCT and neuropsychological measures of EF abilities found in the literature could be attributed to different neuropsychological measures being used across studies as well as developmental differences in the associations between SCT and EF across life stages. Despite some of these findings, recent neuroimaging results report both structural and functional differences in children endorsing SCT consistent with the EF literature. Specifically, researchers discovered that the dorsal areas of the frontal lobes, a region commonly implicated in general executive function, sustained attention, and other higher order cognitive processes, had meaningful alterations in children endorsing SCT, compared to those without elevated SCT (Camprodon-Rosanas, 2019).

Overall, the ecological validity of cognitive testing has been critiqued, with some suggesting that psychometric tasks do not accurately reflect the EF abilities that are utilized in everyday life (Barkley, 2012). Still, further examination of SCT and performance on neuropsychological measures of EF in both college and non-college samples is certainly necessary, as the results to date could best be described as inconclusive. However, if SCT is indeed a disorder that is characterized at all by *any* EF deficits, one might particularly expect temporal processing abilities to be impaired, and this is where the current study will make its primary contribution.

**Pathological mind wandering and SCT**

Despite the ambiguity of association between SCT and EF abilities (see above), there is good theoretical reason to think that some specific EF abilities may be related to both SCT and diminished temporal processing, or the ability to process time-related information**.** One noted theory of SCT is that the disorder may be a form of “pathological mind wandering” (Barkley, 2014, p. 447). Mind wandering can be described as “a common everyday experience in which attention becomes disengaged from the immediate external environment and focused on internal trains of thought” (Schooler et al., 2014, p. 1). The concept of mind wandering comprises its own body of research in the field of psychology, with many studies linking it to EF. Several theories (e.g., McVay & Kane, 2012; McVay & Kane, 2010; Schooler, Smallwood, Christoff, Handy, Reichie, & Sayette, 2011; Smallwood & Schooler, 2006) now dominate the mind wandering literature. Though there are noted differences in these developing theories, each model suggests that the executive control system (e.g., regions of the frontal lobes such as the dorsolateral prefrontal cortex, anterior cingulate cortex, and orbitofrontal cortex), which is believed to manage higher cognitive processes (i.e., EF abilities), are involved in the onset and maintenance of task-unrelated thoughts (i.e., mind wandering). As humans cannot attend to all important stimuli at once, the executive control system works by allocating cognitive resources to the current demands of the external environment (Pachai, Acai, LoGiudice, & Kim, 2016). In sum, when the mind wanders, theoretically one’s executive control shifts away from the primary required task, often to the processing of personal thoughts and goals (Smallwood & Schooler, 2006).

Of the extant research literature investigating EF and SCT, it is apparent that the same EF processes hypothesized to be key features of mind wandering are also the same EF abilities found to be diminished in SCT (e.g., working memory, processing speed). For example, several studies to date have shown that working memory is negatively associated with SCT in children, adolescents, and adults, even when controlling for ADHD-IA (Barkley, 2012; Diamond, 2005; Fassbender & Schweitzer, 2015; Willcutt et. al, 2014). Relatedly, individuals with lower working memory capacity have been shown to have less of an ability to inhibit mind wandering (i.e., maintain focus on outside information in the face of distraction, interference, and/or shifts in conscious focus; Kane et al., 2007). As such, they are essentially using their EF system to focus on mind wandering instead of focusing on the other tasks at hand (Franklin et al., 2014). Working memory capacity is directly influenced by processing speed, with slower processing speeds resulting in having more difficulty holding information in working memory (Baddeley, 1992). As stated above, processing speed has also been shown to be slower in individuals who endorse high SCT (Adams, Milich, & Fillmore, 2010; Garner, Marceaus, Mrug, Patterson, & Hodgens, 2010; Milich et al., 2001; Tamm, Brenner, Bamberger, & Becker, 2016; Willcutt et al., 2014). Inhibition is also important in the prevention of mind wandering, as one must be able to inhibit, or restrain from, focusing on other distractions, whether they be internal or external (Kam & Handy, 2014). Studies of SCT and inhibition have shown that though inhibition is not a unique deficit of SCT, deficits in this domain still can exist for individuals with SCT as compared to normal controls, likely due to the impairments in other, related EF abilities. A putative connection between SCT and mind wandering is perhaps strengthened by recent neuroimaging results revealing an association between endorsed SCT symptoms in children and altered functional connectivity in the brain's default mode network, a neural circuit (including the posterior cingulate and medial prefrontal cortical areas, the medial temporal lobes, and parts of the parietal cortex) commonly linked with inattentiveness and mind wandering (Raichle, 2015; Smallwood & Schooler, 2015).

**Temporal processing**

Despite being abstract in nature, psychological time is a universal construct crucial for the effective completion of many human behaviors (Matthews & Meck, 2016; Zakay, 1990). In fact, temporal processing is thought to play a significant role in many different cognitive functions (Foster et al., 2013). It encompasses abilities such as verbal time estimation, time reproduction, time discrimination, time management, and time orientation (e.g., understanding concepts such as “past” and “future” time; Grondin, 2010; Moll, Göbel, Gooch, Landerl, & Snowling, 2016). Temporal processing abilities are important in daily life as they provide one with the ability to formulate future plans (e.g., “I will do my homework”) and to execute them in the appropriate context (e.g., “at 6:00 p.m.” or “in five minutes” or “after dinner;” Grondin, 2010). In order to efficiently organize and manage such tasks, one must have the ability to anticipate and predict events, which in turn requires the ability to accurately perceive time intervals (Radonovich & Mostofsky, 2004). As Carelli, Forman, & Mantyla (2008) write, “most cognitive control functions, including planning, task initiation, and coordination, are time-related in that they require compliance with temporal constraints” (p. 372). Thus, understanding temporal processing abilities amongst psychologically and adaptively impaired populations, such as those with SCT, is potentially important to understanding the root causes of maladjustment and to the development of effective, tailored clinical interventions.

EF abilities tend to not be "housed" in one unique brain region, and the same is true for temporal processing abilities. Neuroimaging studies have revealed that *multiple* brain regions facilitate temporal cognition (e.g., the cerebellum, hippocampus, frontal and parietal cortices, the supplementary motor area, and the basal ganglia and associated processes; Gordin, 2010; Fontes et al., 2016), and neuropsychological studies have shown that the perception of time is highly influenced by subjective factors, such as one's cognitive processes (i.e., higher order mental processes, such as perception, memory, language, problem solving, and abstract thinking; Gerrig & Zimbardo, 2002), personality, and emotional states (Di Giovinazzo & Novarese, 2016). Because many brain regions and cognitive processes, including EF, are involved in the experience and processing of time, it stands to reason that deficits in any of these could shift a person's subjective sense of time (i.e., perception of time duration) to be different from the objective duration of any given period or activity (Maniadakis & Trahanias, 2011).

In summary, the preponderance of information provided in the literature thus far suggests that there are likely at least *some* EF deficits in adults who endorse symptoms of SCT, independent of those that might be involved in potentially comorbid ADHD. As EF abilities are particularly important components of temporal processing abilities, one would expect that a person with SCT and its associated EF deficits might also have poor temporal processing skills. Temporal processing has not yet been examined as a potential deficit area in adults with SCT, and this study attempts to begin addressing this gap in the literature.

**Current Study**

As described above, temporal processing involves numerous cognitive processes, many of which involve the EF system (Zinke et al., 2010). Attention, inhibition, working memory, and processing speed all involve the frontal cortex and are related to temporal processing (Valko et al., 2009), and deficits in any of these may impair one's ability to accurately utilize temporal information (Radonovich & Mostofsky, 2004). Importantly, each of these EF abilities have already been shown to be relatively impaired in individuals with SCT. In fact, recent neuroimaging results suggest functional differences in frontal lobe areas in children endorsing high SCT behaviors (Camprodon-Rosanas et al., 2019), regions of the brain also implicated in temporal perception (Fontes et al., 2016). Direct examination of temporal processing's association with SCT, however, has not yet been conducted. The current study examines the extent to which temporal processing abilities in college-aged students are predicted by SCT symptoms and whether measures of component EF abilities are associated with these temporal processing deficits. We hypothesized that participants who endorse more SCT symptoms will have poorer performance on temporal processing measures, and that the association of SCT will be independent from ADHD. Specifically, our objectives and hypotheses were as follows:

1. The first objective was to examine whether SCT was uniquely associated with measures of short-term temporal processing, specifically, time estimation and time reproduction tasks. Though prior studies have observed these two tasks as they relate to ADHD symptom endorsement, no studies exist that have looked at SCT symptom endorsement on a continuous scale. We hypothesized that level of SCT-related behaviors endorsed from self-report measures would predict variance on the short-term temporal estimation (hypothesis one) and temporal reproduction (hypothesis two) tasks. Because recent evidence suggests SCT is its own construct, we expected these findings to remain even when controlling for ADHD. Of note, durations encompassing what constitutes as "short-

term" often vary in the literature, though generally involve lengths of only several seconds. From here on, all reference to "short-term temporal processing" tasks serve to distinguish that from the longer temporal processing tasks described below (i.e., short-term temporal processing tasks in this study ≤ 60 seconds whereas long-term temporal processing tasks ≥ 5 minutes).

2. The second objective was to examine whether SCT uniquely predicted performance on long-term temporal processing tasks. Following a study by Prevatt, Proctor, Baker, Garrett, & Yelland (2011), a task typically requiring ten to twenty minutes to complete was required for all study visits (see Methods below), and a prospective (i.e., before completing the task) and retrospective (i.e., after completing the task) estimate was gathered. We hypothesized that SCT would significantly predict performance on each estimation (hypotheses three and four, respectively), even when controlling for ADHD. As an additional measure of long-term temporal estimation abilities, in-vivo estimates of elapsed time were also collected throughout the study visit (see Method). In line with our other hypotheses, we expected level of SCT symptom endorsement would significantly predict total accuracy of participants' in-vivo time estimates (hypothesis five).

3. Finally, our last objective was to examine whether SCT was uniquely associated with self-reported temporal processing abilities. In line with other findings, we expected SCT to uniquely predict poorer EF in the domain of self-management to time (hypothesis six) and self-perceived temporal processing abilities (hypothesis seven).

## Method

### Participants and procedure

This study was approved by the Institutional Review Board (IRB) at Appalachian State University (ASU) in Boone, North Carolina. Participants were 98 college student adults enrolled at ASU who were recruited from the university's Psychology Subject Pool, using the SONA online system. A statistical power analysis indicated that a sample of at least 84 participants was required to detect medium-sized effects ($r = .15$, $\alpha = .05$, $\beta = 0.2$). Participants ranged in age from 18 to 28 years old ($M = 19.87$, $SD = 1.75$) and two-thirds identified as female (66%, $n = 64$). The majority (90.7%) of participants self-identified as White or Caucasian/European American; the remaining participants self-identified as Asian (2.1%), Black or African American (2.1%), Biracial or Multi-racial (3.1%), or Unknown (2.1%). Only 8.3% of participants self-identified as Hispanic or Latino/a. Most participants (50.5%) were in their freshman year of college, while the remaining participants were in their sophomore (25.8%), junior (16.5%), and senior (7.2%) year. Although a formal psychiatric assessment or diagnosis was not conducted in the context of this study, participants were asked to report past and present health status via self-report questionnaires. Demographic and health-related information on the sample is provided in Table 1.

Upon signing up for a study slot online, each participant completed an approximately two-hour-long study visit in a private laboratory setting in the Department of Psychology at ASU led by the principal investigator or a trained research assistant. After reviewing the informed consent form (see Appendix B), study participants filled out a series of questionnaires assessing personal health and other relevant background information. After finishing all study questionnaires, participants completed an abbreviated neuropsychological test battery (i.e., the Digit Span, Information, Coding, and Figure Weights from the *Wechsler Adult Intelligence Scale, Fourth Edition* [WAIS-IV; Wechsler, 2008]) to provide an estimated full scale IQ (FSIQ) composite. Lastly, participants engaged in tasks intended to assess temporal processing, specifically short- and long-term time estimation abilities and time reproduction abilities adapted from previously published papers on the psychology of time (e.g., Bauermeister et al., 2005; Prevatt et al., 2011; Barkley et al., 2001). Three in-vivo time estimation data points were also collected during the study visit: after completion of the self-report measures (in-vivo estimate 1), after completion of the WAIS-IV subtests (in-vivo estimate 2), and after completion of the entire study visit (in-vivo estimate 3). Given the nature of the experiment, access to clocks, wrist watches, cell phones, and other devices with a clock or audible timer during the study visit was not allowed.

**Measures**

**Demographics and medical history form.** Demographic and medical history information were obtained through the participant's completion of a Demographics and Medical History form created specifically for this study (see Appendix C). Information collected included standard demographic information (e.g., age, sex, race, ethnicity) and year in college.

**SCT.** Correlations between two independent measures of SCT (i.e., the Barkley Adult ADHD Rating Scale [BAARS-IV] and Adult Concentration Inventory [ACI]; see below) were high ($r = .84$, $p < .01$). As such, one measure of SCT was created by converting the raw scores from the BAARS-IV: Self-Report: Current Symptoms SCT section (8 items; $\alpha = .88$ in this sample) and the 16 items from the ACI ($\alpha = .90$ in this sample) to z-scores and averaging the two to create one composite.

***Barkley Adult ADHD Rating Scale.*** In addition to measures of ADHD (see below), the BAARS-IV also includes nine symptoms reflective of the current SCT domain ($\alpha$ = .86 in this sample). The nine SCT items on the BAARS-IV include: being prone to daydreaming when should be concentrating on something or working, having trouble staying awake or alert in boring situations, being easily confused, being easily bored, feeling spacey or "in a fog," feeling lethargic or more tired than others, being underactive or having less energy than others, being slow moving, and appearing not to process information as quickly or as accurately as others. Participant responses for all BAARS-IV SCT items were made on a four-point Likert-type scale ranging from 0 (*Never or Rarely*) to 3 (*Very often*). Total SCT current symptom raw scores range from 9 to 36. A total raw score of 12 equates to the 50$^{th}$ percentile, 19 to the 85$^{th}$ percentile, 21 to the 90$^{th}$ percentile, and a raw score of 29-31 falling within the 98$^{th}$ percentile, according to norms provided for 18-to-39-year-olds (Barkley, 2011).

***Adult Concentration Inventory (ACI).*** The Adult Concentration Inventory (Becker et al., 2017) is a newly-developed self-report measure for assessing SCT symptoms in adulthood. The ACI includes 16 items ($\alpha$ = .88 in this sample), identified in a recent-meta-analysis (Becker et al., 2016) as optimal for distinguishing between SCT and both ADHD-IA and internalizing symptoms. The items are rated on a four-point Likert-type scale ranging from 0 (*Not at all)* to 3 (*Very often*) referencing the previous six months with higher scores reflective of more SCT symptom endorsement.

**ADHD.** The Barkley Adult ADHD Rating Scale, Fourth Edition (BAARS-IV) Current Symptoms Scale (Barkley, 2011) is a self-report measure used to assess current (i.e., past six months) symptoms of ADHD per the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV-TR; APA, 2000) criteria, including inattention (nine items; $\alpha$ = .89 in this sample), hyperactivity (five items; $\alpha$ = .69 in this sample), and impulsivity (four items; $\alpha$ = .81 in this sample). Participant responses were made on a four-point Likert-type scale ranging from 0 (*Never or Rarely*) to 3 (*Very often*). By adding the three ADHD scores together, one can also compute the Current ADHD total symptom score, which was used in the present study. The total ADHD current symptom raw scores range from 18 to 72. A total raw score of 22 equates to the 50$^{th}$ percentile, 35 to the 85$^{th}$ percentile, 36 to the 90$^{th}$ percentile, and a total raw score of 49-53 falling within the 98$^{th}$ percentile, according to norms provided for 18-to-39-year-olds (Barkley, 2011).

**FSIQ.** A four-subtest short form of the WAIS-IV (Wechsler, 2008) was used to estimate global intellectual and cognitive functioning. The WAIS-IV four-subtest estimated full scale IQ (FSIQ) for each participant was calculated using the Tellegen and Briggs (1967) procedure outlined in Sattler & Ryan (2009). Specifically, the four subtests Digit Span (DS), Information (IN), Coding (CD), and Figure Weights (FW) were used for FSIQ estimation, giving a short form IQ reliability coefficient of. 96, validity coefficient of .94, and 95% confidence interval of ± 7 (Sattler & Ryan, 2009). These four subtests for the short-form were chosen as they represent each WAIS-IV index (e.g., working memory, verbal comprehension, processing speed, and perceptual reasoning, respectively), and are relatively easy and brief to administer. Derived estimated FSIQ scores were used for potential statistical control in analyses. See Table 3 for WAIS-IV descriptive statistics for this sample.

**Short-Term Temporal Processing Tasks.** To measure short-term temporal processing abilities-- specifically, aptitude for time estimation and time reproduction-- participants were asked to complete three separate tasks, described below. As previously stated, throughout the duration of the study visit, participants did not have access to time-telling devices.

***Short-term time estimation.*** For the short-term time estimation task, participants were asked to verbally estimate time durations presented to them using procedures adapted from Barkley, Edwards, Laneri, Fletcher, and Metevia (2001). For consistency and precision, an automated computer program was developed for this task. For each item, a red square appeared on the center of the computer monitor for the allotted number of seconds (see below). The participant was then asked to verbally indicate to the research assistant how long, in seconds, the red square was visible on the screen. The research assistant signaled the beginning and end of each time duration by verbally indicating (i.e., "Next") to the participant when he or she was moving to the next item. Seven different time intervals (6, 10, 13, 18, 25, 47, and 60 seconds) were each presented to participants twice, in two blocks. The five target intervals intended for analysis were: 10, 18, 25, 47, and 60 seconds. The remaining two time intervals, 6 and 13 seconds, were used for "filler" time estimates and were not included in any analyses (as per Barkley et al., 2001). The time intervals were presented to participants in a mixed order. On the first trial, the seven time intervals were presented in ascending order. On the second trial, the time intervals were presented as follows: 10, 13, 60, 25, 18, and 47. Before beginning the task, a practice trial with a time duration of 5 seconds was administered to ensure the participant understood task instructions. All participants received the time durations in the same order of presentation.

***Time reproduction.*** For this task, participants were asked to reproduce an interval of time that was presented to them (i.e., to physically respond once he or she perceived the same length of time that a red square was visible on the computer screen to have elapsed). The method of presenting the time durations was the same as in the short-term time estimation task and the same time intervals were presented (see above). However, instead of verbally estimating the sample time duration as in the task above, the participant was asked to *reproduce* the same time interval him- or herself by clicking "Start" and "Stop" buttons using a computer mouse in an attempt to reproduce each length of time presented to them in this task. When the participant clicked the "Start" button, a red square appeared on the computer monitor and an invisible timer started. When the participant believed he or she had reached the length of time that was previously presented, he or she then pressed the "Stop" button to remove the red square and thereby end the timer.

For the short-term time estimation task, the participant's scores on each trial was the length of time responded rounded to the nearest second. For the time reproduction task, item responses were rounded to the thousandths digit (i.e., the third decimal place) given the computer program's ability to be more precise with item estimates. As in Barkley et al. (2001), the scores were then converted to an absolute discrepancy score by subtracting the given sample duration from the time estimated or produced by the participant and eliminating the sign, whether positive or negative. Calculating absolute discrepancy values in this manner gave insight into the severity of the participants' errors in timing, regardless of the directionality (i.e., under- or over-estimates of reproductions) and was a method used in the remaining tasks described below.

**Long Term Temporal Processing Tasks**

***Long-term time estimation***. For the long-term time estimation measure, participants completed a task adapted from Prevatt, Proctor, Baker, Garrett, & Yelland (2001) that was designed to be longer in duration, more academically oriented, and of increased complexity as compared to standard time estimation tasks (i.e., tasks involving just a stopwatch or timer and verbal estimations or reproductions, as explained above). In this task, participants were asked to sort four types of documents-- magazine covers, film reviews, journal articles, and newspaper front pages-- into four different stacks by category with the most recent date on top and then into alphabetical order within each year (by using the first word of the document title). A total of 80 documents were sorted. All documents were prearranged into a specific order which was maintained for all participants. Before beginning the scored task, participants completed a short sample of 15 documents to ensure they understood instructions. If a mistake was made during practice, the mistake was explained and corrected by the researcher, and the instructions repeated until understanding was ensured. Before beginning the task, each participant was asked to answer the question, “How many minutes do you believe it will take you to complete the task?” Participants were then instructed to begin sorting the documents and were told to verbally indicate to the researcher when they finished. The researcher used a stopwatch to record the amount of time it took; generally, this took more than 10 minutes. After the participant signified completion of the task, they were asked to answer the question, “Now that you have completed the task, how many minutes do you believe it actually took to complete?” The prospective difference and retrospective difference scores were used as dependent variables. This temporal estimation task, unlike others, taps the abilities to estimate time over a period of minutes as opposed to seconds. It is suggested that it has high ecological validity, as it mimics demands commonly required at this age (e.g., while in college classes, associated tasks that are lengthy and tax working memory; Prevatt et al., 2001).

***In-vivo time estimates:*** As an additional measure of timing abilities, participants were asked to complete several in-vivo estimates in order to gauge their time discrimination abilities in real-time. When each participant arrived for the study visit, the researcher recorded the time of day on a separate record form (see Appendix D). At three time points throughout the study (i.e., after completion of all self-report forms, after completion of the WAIS-IV subtests, and after completion of the entire study visit), participants were asked to state how long, in minutes, they believed they had been participating at the visit thus far. The researcher noted the participant's verbal estimation of time duration along with the actual duration for each item, and a total in-vivo absolute discrepancy score including all three time estimates was calculated. Of note, the actual duration of time elapsed for each in-vivo estimate varied between participants as in-vivo estimates were solicited after completion of specific *events*, not at pre-determined time intervals.

**Self-Report Measures of Temporal Abilities**

***Barkley Deficits in Executive Functioning Scale – Adults (BDEFS-A).*** The BDEFS-A is a behavioral questionnaire used to evaluate clinically significant dimensions of adult executive functioning. The measure has been found to be significantly associated with self-ratings of impairment and reflects impairment in various domains of life (e.g., educational, occupational). The entire BDEFS-A is comprised of five sections representing different domains of EF, but only the Self-management of time domain (21 items; e.g., "Procrastinate or put off doing things until the last minute" and "Waste or mismanage my time") will be used in the current study (α = .94 in this sample). Items are rated on a four-point Likert-type scale ranging from one (*Never or Rarely*) to four (*Very often*), and scores reflect the sum of item responses for that domain with higher scores indicating more impairment in that domain (Barkley, 2011).

***Sorrell-Canu Orientation to Time Measure (SCOTT).*** The SCOTT is a 23-item, self-developed questionnaire (see Appendix E) assessing participant's self-perceived temporal processing abilities (Sorrell & Canu, 2018), such as accurately estimating durations of time (e.g., "I am able to estimate what time of day it is without looking at a clock," and "I underestimate the time required to complete a task"). Items were generated after a review of the temporal processing and the SCT literature (α = .88 in this sample). Responses for each item are indicated on a five-point Likert-type scale ranging from 0 (*Very Untrue*) to 4 (*Very True*). Thirteen of the items are reverse scored. The sum (range 0-92) of the items on the SCOTT measure reflect self-perceived ability to estimate, track, and manage time, with lower scores indicating more difficulties. All items have high face validity for temporal processing (e.g., "I have difficulty estimating how much time it will take me to complete a task" [R], "I am accurately able to estimate the length of a movie I have watched"). See Sorrell & Canu (2018) for more information regarding the SCOTT measure.

**Data Analytic Plan**

Before running analyses, descriptive statistics were computed to characterize the sample and to ensure statistical modeling assumptions were met (see Table 2). Mindful that estimated FSIQ may account for findings on our dependent variables, Pearson correlations were computed for the four individual subtests of the WAIS-IV and total estimated FSIQ with all dependent variables (see Table 4). Given that no significant correlations were found between the WAIS-IV and the dependent variables, estimated FSIQ was removed from all analyses as a predictor variable. Correlations were also computed between SCT (see Table 5) and total ADHD (see Table 6) predictor variables and all dependent variables. Both SCT and total ADHD significantly correlated with at least some dependent variables. As such, ADHD was retained along with SCT in the analytic models that follow.

All data was analyzed using the computer software SPSS (Version 24; IBM, 2013). Seven multiple regression analyses were conducted to evaluate how well measures of SCT predict the seven differing temporal processing variables. As explained above (see Sluggish Cognitive Tempo in Measures), one measure of SCT was created using the BAARS-IV: Self-Report: Current Symptoms (SCT section) and the ACI. Each multiple regression analysis included two variables (i.e., the composite SCT measure and the BAARS-IV ADHD total raw score[1]) entered simultaneously as predictors of each of the seven criterion variables (i.e., short-term time estimation and time reproduction absolute difference scores, long-term prospective and retrospective time estimation absolute difference scores, in-vivo time estimation absolute difference score, total raw BDEFS Self-management to time and SCOTT scores).

After this preparatory work, seven multiple regression analyses were conducted to test the seven hypotheses. In each, SCT and ADHD were entered in a single block as predictor variables. Independent (criterion) variables for the seven regressions, in order of the hypotheses, were short-term time estimation absolute discrepancy scores, time reproduction absolute discrepancy scores, prospective time estimation absolute discrepancy scores, retrospective time estimation absolute discrepancy scores, in-vivo time estimation absolute discrepancy scores, BDEFS Self-management to time total raw scores, and SCOTT total raw scores. By examining and interpreting the *F*-and *R*-squared values, how much variance in the dependent variables are accounted for by both ADHD and SCT independently will be determined (Statistics Solutions, 2013).

# Results

## Short Term Temporal Processing Tasks

As previously noted (see Measures), absolute discrepancy scores for the short-term time-estimation and time-reproduction items were computed and summed into total absolute discrepancy values. Due to significant right skew of the distributions, a logarithmic transformation was applied to reduce skewness and non-normality and to transform the original variables into a distribution more consistent with the assumptions of parametric statistical analyses (Field, 2013).

Neither the first regression analysis predicting short-term time estimation nor the second regression analysis predicting time reproduction indicated the SCT+ADHD model to have a significant association. Further, neither predictor variable emerged as a statistically-significant independent predictor in either analysis (see Table 7 for further statistical detail).

## Long-Term Temporal Processing Tasks

For each long-term time estimation task, absolute discrepancy scores were computed and summed to produce one total score (i.e., the sample duration was subtracted from the time estimated by the participant, and the sign eliminated, whether positive or negative). For each set of variables, a logarithmic transformation was applied to raw values to adjust for distribution skewness and non-normality.

The linear combination of SCT+ADHD in the fourth regression analysis predicting accuracy of prospective time estimation (i.e., the absolute value of the discrepancy between estimated time to complete the document sorting task before beginning versus actual time it took) was not significant (see Table 8). However, SCT was found to be a significant independent predictor of participants' duration estimations for completing the document sorting task. ADHD, in contrast, was not. This provides some support for the hypothesis that there would be a positive relationship between SCT and error in long-term time estimation, as participants who endorsed higher SCT had larger discrepancies between predicted amount of time to complete the document sorting task and the actual time it took.

Contrary to the a priori hypothesis, results from the fifth and six regression analyses predicting performance on retrospective long-term time estimation (i.e., the absolute value of the discrepancy between estimated time to complete the document sorting task after completing versus actual time it took) and in-vivo time estimates (i.e. the absolute discrepancy between each of the three time estimations and sample durations) were not significant. Further, neither SCT or ADHD emerged as a statistically-significant independent predictor in either analysis (again, see Table 8 for further statistical detail). These results suggest that neither self-reported SCT nor ADHD behaviors contribute meaningfully to the ability to accurately predict the passing of time during the two-hour visit.

**Self-Report Measures of Temporal Abilities**

In the sixth and seventh regression models predicting the self-management to time and self-perceived temporal abilities, respectfully, a linear combination of SCT+ADHD explained a statistically significant amount of variance (see Table 9). Both predictor variables emerged as statistically significant independent predictors in the sixth multiple regression analysis whereas only the SCT score was a significant predictor in the seventh. Regarding participant's self-perception of time orientation (hypothesis seven), these results indicate a negative relationship between the construct of SCT and the SCOTT measure, agreeing with the seventh a priori hypothesis and suggesting that individuals who endorse more SCT-related behaviors perceive themselves to have more difficulty with time orientation (i.e., lower SCOTT scores).

## Discussion

The intent of this study was to examine the relationship between self-reported SCT and temporal processing in college students. Previous studies have examined time estimation and reproduction abilities in children and adults with and without ADHD, but only one, to our knowledge, has focused on the relationship with SCT (i.e., Bauermeister et al., 2005), and none have examined SCT behaviors on a continuous scale. Overall, the current findings provide some limited support for an association between SCT and lower scores on measures of temporal processing.

Before discussing the results of this study along with the relevant clinical implications, it is important to address the idea of SCT reflecting its own separate diagnostic entity. At this time, it is evident that more research is needed before any conclusions regarding the status of SCT can be made. In their meta-analytic review, Becker et al. (2015) suggest several imperative directions for SCT research in the future, including: (a) the examination of the developmental progression, moderators, mediators, and underlying mechanisms that link SCT to demographic, mental health, or impairment domains, (b) the examination of SCT beyond the population of ADHD, (c) the extension of research to use multi-methodological approaches (i.e., genetic and neuroimaging methodologies) to the study of etiology and impairment, and (d) the advancement of psychometric research to develop a clear set of constructs affiliated with SCT. Until these advances in the research have been made, Becker et al. (2015) “do not recommend describing SCT in diagnostic terms at this time” (p. 175). To do so prematurely, they argue, could create confusion amongst researchers, clinicians, and families, as well as the broader public. As such, the discussion and general findings have been presented in terms of SCT characteristics, without an assumption of a firmly established psychopathological syndrome.

**Temporal Processing Tasks**

Findings from the current study suggest that self-endorsement of SCT-related behavior may not significantly relate to *performance* on laboratory time reproduction tasks, and that SCT’s relationship to time estimation performance may be limited. Herein, only in *prospective* estimation of the duration of a long-term task (i.e., document sorting) was any predictive association detected.

Although not supportive of the original hypotheses, in the context of previous findings, the results from the present study make theoretical sense. To date, the literature suggests that there are no significant differences between ADHD and normal controls in short-term time estimation abilities across the lifespan, though some differences do exist in temporal reproduction abilities (see Bauermeister et al., 2005, and Barkley et al., 2001). Consistent with findings from Bauermeister et al. (2005) who examined SCT in addition to ADHD traits, SCT scores were not significantly correlated with time reproduction in the present study. Time reproduction tasks are thought to be more cognitively demanding than time estimation tasks, particularly for the formers’ reliance on working memory (holding the sample duration in mind) and inhibition (regulating motor response to signal the end of the reproduction duration). Given that inhibition does not appear impaired in individuals with SCT, and that the associations with SCT and working memory are currently unclear, it is not necessarily surprising that SCT does not predict meaningful variance in the short-term temporal reproduction task. In the present study, SCT scores and performance on a working memory task (WAIS-IV Digit Span subtest) did not significantly correlate ($r$ =.01) . Furthermore, working memory did not significantly correlate with any temporal processing variables. Unfortunately, we did not have a specific measure of inhibition, so it is not clear whether inhibitory deficits contributed to this finding.

The document sorting task was created by Prevatt et al. (2011) to tap prospective and retrospective temporal estimation after completing an assignment and is a measure that was longer in duration (i.e., minutes instead of seconds), more academically oriented, and of increased complexity, as compared to other tasks in the published literature. Their study differs from the current one as it examined college students with and without ADHD, with no measure of SCT included. Conflicting with the results from the current study, Prevatt et al. (2011) found differences in retrospective instead of prospective time estimates. Though further investigation is encouraged for clarity, our data reveal that SCT does predict some of the variance found in these longer-term tasks. It is possible that observing SCT from a dichotomous instead of a continuous approach when analyzing the dependent variables could provide more insight on group differences. Perhaps relationships would have been detected if groups had been defined based on self-report measure cut-offs that indicate “clinical” and “non-clinical” status. Finally, in Prevatt et al., additional dependent variables, including participant’s confidence ratings in their estimations (e.g., by asking participants “How confident are you that your answer is accurate?”) and number of errors on the document-sorting task, were evaluated. It is possible that inclusion and evaluation of these additional variables in the present study may also reflect group differences, potentially distinguishing SCT as its own construct with noticeable impairment.

Related research suggests that errors in time estimation and reproduction tend to increase with intervals of longer duration. Though beyond the scope of the present paper, it is possible that examination of duration-specific estimates (i.e., absolute discrepancy errors for the five target intervals of 10, 18, 25, 47 and 60 seconds) amongst all short- and long-term temporal processing tasks would provide additional information on the ability for SCT to predict variance. For example, it is possible that duration-specific estimates of in-vivo estimates one, two, and three may reveal more information when examined independently. Though all time-related cues were removed from the study room, participants had a general awareness that the study visit was intended to last approximately two hours when originally signing up for the study online and in reviewing the informed consent. As such, it is possible that this knowledge could have contributed to relative accuracy of in-vivo time estimates, particularly for the third and final estimate, which occurred at the end of the study visit.

**Self-Report Measures of Temporal Abilities**

The present findings suggest that in comparison to performance-based measures of temporal processing, self-endorsement of SCT-related behavior appears to significantly relate to self-report measures of temporal processing abilities. Consistent with prior research, our results demonstrate that self-endorsed SCT characteristics predict relatively lower scores in the EF domain of self-management to time (Becker et al., 2017; Jarrett et al., 2017) and self-perception of time-related abilities (Sorrell & Canu, 2018), such as accurately estimating durations of time. This supports the original hypotheses (hypotheses six and seven), particularly given the proposed theoretical underpinnings of SCT. Albeit more research is needed to distinguish exactly what EF impairment is uniquely associated with SCT, findings from previous studies suggest there are at least some deficits independent from ADHD. SCT is, after all, associated with mind-wandering (Barkley, 2014), which is reliant on EF abilities that emerge from brain regions that are associated with temporal processing in daily life activities (Valko et al., 2009; Zinke et al., 2010).

The contrasts found between self-report and task-based measures of temporal processing in the current study are consistent with findings from other studies where SCT symptoms are related to multiple self-reported EF domains but are less clearly associated with laboratory-based tasks of neuropsychological functioning (Jarrett et al., 2017; Becker et al., 2017). Considering the uniformity with the larger literature, the current results are not surprising. These discrepancies between self-report and laboratory-based measures could be due to myriad reasons. When considering SCT's theoretical relation to pathological mind-wandering, one would expect that individuals endorsing higher levels of SCT generally find themselves engaging in cognitions unrelated to their current environmental demands. However, it is possible that in the present study participants demonstrated increased alertness, attentiveness, and persistence on our laboratory-based tasks merely because of their awareness of being in an experiment for course credit (i.e., observer effects).

Relatedly, Barkley and others suggest that the discrepancy between self-report and laboratory-based measures may be related to the notion that "EF tests have low or no ecological validity and low or no relationships to various domains of impairment in contrast to ratings of EF" (Barkley, 2015, p. 441), leading to EF ratings demonstrating a different pattern of results for SCT than do laboratory-based measures of EF. Perhaps in the context of the current study in which college students participated in the two-hour study visit for college course credit, these impairments in temporal processing and their related effects on performance may not be as prominent compared to self-report measures which capture abilities and tendencies generally present in everyday functioning, where impairments are observed**.** For example, when considering the overall symptom pattern of SCT in the larger context of the existent literature, it appears that SCT consistently correlates with impairments in the self-organization/problem-solving domains of EF. This domain largely reflects the one's ability "to organize thoughts, actions, and writing, think quickly when encountering unexpected events, and invent solutions to problems or obstacles encountered while pursuing goals" (Jarrett et al., 2017; p. 681), abilities consistent with the conceptualization of SCT as comprising slower processing. These self-organization and problem-solving domains of EF are relevant to temporal processing and the current study as "the preparation of fast responses benefit from the ability to predict precisely the point in time when an impending event requires a response" (Toplak, Rucklidge, Hetherington, John, & Tannock, 2003, p. 88). In addition, "precise representation of temporal information is required for the ability to organize and plan sequences of actions, particularly when sequences of novel or unskilled movements are required" (Toplak et al., 2003, p. 88). It could be that differences in temporal processing related to SCT are subtle (i.e., distinguishable only at the level of milliseconds) and therefore are unable to be detected by the laboratory-based tasks in this study which recorded durations at the level of seconds and minutes. Indeed, if the temporal discrepancies for individuals endorsing SCT are existent, even at the level of milliseconds, these potential deficits may have "cascaded effects on the temporal organization of behavior," (Toplak et al., 2003, p.88) including prioritizing activities, planning ahead, preparing for assignments and upcoming events, and meeting deadlines, capabilities that are important daily.

**Conclusion**

Our findings provide some insight on the association of SCT characteristics to temporal processing abilities in college-aged students, information relevant for future clinical implications. SCT accounted for significantly more variance in self-report measures compared to performance-based measures of temporal processing, and did so independent of ADHD's association. These results appear consistent with previous studies indicating that SCT and ADHD are indeed empirically distinct constructs. This study goes further than previous research in temporal processing and attentional disorders in that it specifically investigates the characteristics of SCT using a dimensional approach. For example, instead of categorizing participants in two groups (i.e., those with and those without SCT), this study examines the strength of SCT symptom endorsement with the dependent variables (i.e., temporal processing tasks). This study revealed that participants who endorsed more SCT-related behaviors had larger discrepancies between predicted amount of time to complete the long-term (i.e., document sorting) task and the actual time it took them to complete it, as compared to those with fewer SCT traits. This finding is important as being on time for class, arriving on time for appointments, managing one's schedule to allow sufficient time for studying and other demands, and starting a project or homework assignment with enough time to spare are all common academic tasks that might be linked to time estimation abilities (Prevatt et al., 2011) and might, therefore, be poorly performed by students with significant SCT. Further, impairment and difficulties indexed on both the BDEFS and SCOTT self-report measures that reflect the self-discipline and time management needed for adequate success in college were found to be positively associated with SCT characteristics. As such, if confirmed in future studies, the findings from the present study may have significant clinical and nosological implications for a putative disorder that is specifically related to SCT.

Overall, this study elucidates the relevance of assessing for SCT characteristics and possibly associated functional and cognitive impairments in college students. The identification of individuals endorsing SCT-related behaviors and subsequent impairment could lead to the development, or at very least, refinement, of clinical interventions (e.g., assessment, conceptualization, and treatment planning) among college students.

**Limitations and future directions**

The clinical significance of this study should be considered in light of several existing limitations. One notable limitation of this study is its reliance on self-report measures. Although self-reports are generally easy and cost-effective to use, there are some disadvantages, including the reliance on participant comprehension of measures as well as accurate recall abilities (e.g., over- or under-reporting of symptoms; Barkley, 2011; Sibley et al., 2012). Though still a clinically valid measure of assessing impairment, collecting additional sources of data (e.g., from parents, peers, romantic partner, teachers) could provide additional input relevant to study analyses (Jarrett et al., 2017; Sibley et al., 2012). Further, collecting academic adjustment information, such as students' grade point averages (GPA), could also shed light on "real-life" adaptation in college and be utilized in future studies of SCT as either a predictor, moderator, and/or outcome variable. Another limitation of this study is the exclusive use of a college student sample, along with the limited age range (i.e., 18 to 28 years) and relative lack of cultural diversity. Future studies may benefit from recruiting a diverse, community sample, one that taps a variety of ages (e.g., children, adolescents, and older adults). This could help us to understand how the construct of SCT manifests in the broader population and thereby boost external validity and generalizability. Furthermore, these students were recruited from a psychology department research pool versus clinical referral, meaning that the ceiling of their SCT, ADHD, and other psychopathological traits is likely less severe than community-based or clinically-referred adults. Perhaps only truly “severe” SCT, such that could possibly be relevant to a pathological syndrome, is robustly associated with EF and temporal processing issues, and this may have been underrepresented herein.

Finally, as this study is one of the first to directly examine the relationship between temporal processing and SCT characteristics, it is largely exploratory in nature. Although results from this study suggest there may be some connection between SCT trait endorsement and temporal processing abilities, it is still too early to interpret how strong of a predictor this construct is by itself. It may be of note that descriptive statistics show that this sample endorsed experiencing somewhat fewer SCT-related characteristics in the previous six months on the ACI ($M$ = .97, $SD$ = 0.80) in comparison to the initial psychometric validation study ($M$ = 1.16, $SD$ = 0.58) of over 3,000 undergraduate students (Becker et al., 2017). However, scores on the BAARS-SCT scale ($M$ = 15.18, $SD$ = 5.08, range = 9 to 29) seemed to closely approximate the norms established for the 18-to-39-year-old population (Barkley, 2011). Still, perhaps this is an indication that future research might be well-advised to ascertain a sample of students who generally endorse higher SCT to adequately test the effects of the full range of SCT on temporal processing. Furthermore, while the existing literature does suggest that the cluster of behaviors collectively termed “sluggish cognitive tempo" is statistically distinct, empirical research validating it as a possible disorder is still in its infancy. A lot of questions remain regarding whether individuals with SCT can be clinically distinguished from others who meet criteria for ADHD, depression, anxiety, and sleep disorders, and continued research in this area is needed.

Another direction for future studies may be to consider item-level analyses of the laboratory-based temporal processing tasks used herein, including examination for directionality (i.e., over- versus under-estimations for different time points or intervals), as this study only looked at absolute inaccuracy without examining specific durations. Furthermore, it is worth noting that one of the theoretical possibilities underlying SCT in particular is an evident linkage with internalizing disorders. As such, future research may wish to control for anxiety and depression, examining the role their symptom clusters may have as mediating or moderating variables for SCT's relationship with temporal processing.

While there are a number of limitations present in this initial study, there are also substantial strengths. College education is a unique developmental process marked by increased demands in self-regulation abilities needed to succeed, all while many individuals' personal support systems are suddenly eroded by leaving home (and often their home town). Adequate executive functioning and temporal processing abilities are both important aspects of success for students at this level, and this fact makes studying the connection between these constructs and a putative disorder such as SCT in this population relevant. Second, despite the limitations, this study adds to the growing body of literature on SCT and its related features, contributing additional support for SCT's validity as a construct and suggesting that severe SCT behaviors may relate to impairment in daily life and, more specifically, in temporal processing.

References

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders*. (5th ed.). Washington, DC: Author.

Adams, Z. W., Milich, R., Fillmore, M. T. (2010). A case for the return of attention-deficit disorder in DSM-5. *The ADHD Report, 18,* 1-6. doi: 10.1521/adhd.2010.18.3.1

Araujo-Jiménez, E. A., Jané-Ballabriga, M. C., Martin, A. B., Arrufat, F. J., & Giacobo, R. S. (2015). Executive functioning in children and adolescents with symptoms of sluggish cognitive tempo and ADHD. *Journal of Attention Disorders*, *19*, 507-514. doi:10.1177/1087054713495442

Baddeley, A. D. (1992). Working memory. *Science, 255,* 556-559. doi: 10.1126/science.1736359

Barkley, R. A., Edwards, G., Laneri, M., Fletcher, K., & Metevia, L. (2001). Executive functioning, temporal discounting, and sense of time in adolescents with attention deficit hyperactivity disorder (ADHD) and oppositional defiant disorder (ODD). *Journal of Abnormal Child Psychology, 29,* 541-556. doi: 10.1023/A:1012233310098

Barkley, R.A. (2001). The Barkley deficits in executive functioning scale. New York: Guilford.

Barkley, R. A. (2011). *Barkley Adult ADHD Rating Scale-IV (BAARS-IV)*. New York: Guilford.

Barkley, R. A., Knouse, L. E., & Murphy, K. R. (2011). Correspondence and disparity in the self- and other ratings of current and childhood ADHD symptoms and impairment in adults with ADHD. *Psychological Assessment,* 23, 437–446. doi: 10.1037/a0022172

Barkley, R. A. (2012). Distinguishing sluggish cognitive tempo from attention-deficit/hyperactivity disorder in adults. *Journal of Abnormal Psychology, 12,* 978-990. doi: 10.1037/a0023961

Barkley, R. A. (2013). Distinguishing sluggish cognitive tempo from ADHD in children and adolescents: executive functioning, impairment, and comorbidity. *Journal of Clinical Child & Adolescent Psychiatry, 42,* 161-173. doi: 10.1080/15374416.2012.734259

Barkley, R.A. (2014). Sluggish cognitive tempo (concentration deficit disorder?): Current status, future directions, and a plea to change the name. *Journal of Abnormal Child Psychology, 42,* 117-125. doi: 10.1007/s10802-013-9284-y

Barkley, R.A. (2015). Concentration deficit disorder (sluggish cognitive tempo). In R.A. Barkley's *Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment* (4th ed.) (pp. 435-452). New York, NY: Guilford.

Bauermeister, J. A., Barkley, R. A., Martinez, J. V., Cumba, E., Ramirez, R. R., Reina, G. … Salas, C. C. (2005). Time estimation and performance on reproduction tasks in subtypes of children with attention deficit hyperactivity disorder. *Journal of Clinical Child and Adolescent Psychology, 34,* 151-162. doi: 10.1207/s15374424jccp3401_14

Bauermeister, J. A., Martinez, J. V., & McBurnett, K. (2012). Validity of the sluggish cognitive tempo, inattention, and hyperactivity symptom dimensions: Neuropsychological and psychosocial correlates. *Journal of Abnormal Child Psychology, 40*, 683-697. doi: 10.1007/s10802-011-9602-7

Becker, S. P., Burns, G. L., Garner, A. A., Jarrett, M. A., Luebbe, A. M., Epstein, J. N., & Willcutt, E. G. (2017). Sluggish Cognitive Tempo in Adults: Psychometric Validation of the Adult Concentration Inventory. *Psychological Assessment*. doi: 10.1037/pas0000476

Becker, S. P. (2017). "For some reason I find it hard to work quickly": Introduction to the special issue on sluggish cognitive tempo. *Journal of Attention Disorders,* 615-622. doi: 71/01.1018770/15048710574679127868928

Becker, S. P., Garner, A. A., Tamm, L., Antonini, T. N., & Epstein, J. N. (2017). Honing in on the social difficulties associated with sluggish cognitive tempo in children: Withdrawal, peer ignoring, and low engagement. *Journal of Clinical Child Adolescent Psychology, 48,* 228-237. doi: 10.1080/15374416.2017.1286595

Becker, S. P., Pfiffner, L. J., Stein, M. A., Burns, G. L., & McBurnett, K. (2015). Sleep habits in children with attention-deficit/hyperactivity disorder predominantly inattentive type and associations with comorbid psychopathology symptoms. *Sleep Medicine, 21,* 151-9. doi: 10.1016/j.sleep.2015.11.011

Becker, S. P., Leopold, D. R., Jarrett, M. A., Langberg, J. M., Marshall, S. A., McBurnett, K., Waschbusch, E.G., & Willcutt, E. (2016). The internal, external, and diagnostic validity of sluggish cognitive tempo: A meta-analysis and critical review. *Journal of the American Academy of Child and Adolescent Psychiatry, 55,* 163-178. doi: 10.1016/j.jaac.2015.12.006

Becker, S. P., & Langberg, J. M. (2014). Attention-deficit/hyperactivity disorder and sluggish cognitive tempo dimensions in relation to executive functioning in adolescents with ADHD. *Child Psychiatry and Human Development*, *45,* 1-11. doi:10.1007/s10578-013-0372-z

Becker, S. P., Langberg, J. M., Luebbe, A. M., Dvorsky, M. R., & Flannery, A. J. (2014). Sluggish cognitive tempo is associated with academic functioning and internalizing symptoms in college students with and without attention-deficit/hyperactivity disorder. *Journal of Clinical Psychology*, *70*, 388-403. doi:10.1002/jclp.22046

Becker, S. P., Luebbe, A. M., & Langberg, J. M. (2014). Attention-deficit/hyperactivity disorder dimensions and sluggish cognitive tempo symptoms in relation to college students' sleep functioning. *Child Psychiatry and Human Development, 45,* 675-685. doi: 10.1007/s10578-014-0436-8

Becker, S. P., & McBurnett, K. (2013). Sluggish cognitive tempo in abnormal psychology: An historical overview and introduction to the special section. *Journal of Abnormal Child Psychology, 42*, 1-6. doi: 10.1007/s10802-013-9825-x

Becker, S. P., Fite, P.J., Garner, A. A., Greening, L., Stoppelbein, L., & Luebbe, A. M. (2013). Reward and punishment sensitivity are differently associated with ADHD and sluggish cognitive tempo symptoms in children. *Journal of Research in Personality, 47,* 719-727. doi: 10.1016/j.jrp.2013.07.001

Camprodon-Rosanas E, Pujol J, Martínez-Vilavella G, Blanco-Hinojo L, Medrano-Martorell S, Batlle S, Forns J, Ribas-Fito N, Dolz M, Sunyer J. (2019). Brain structure and function in school-aged children with sluggish cognitive tempo symptoms. *Journal of the American Academy of Child & Adolescent Psychiatry, 58,* 256-96. doi: 10.1016/j.jaac.2018.09.441

Carelli, M. G., Forman, H., & Mäntylä, T. (2008). Sense of time and executive functioning in children and adults. *Child Neuropsychology*, *14*, 372-386. doi: 10.1080/0929704070144141

Carlson, C. L., & Mann, M. (2002). Sluggish cognitive tempo predicts a different pattern of impairment in the attention deficit hyperactivity disorder, predominantly inattentive type. *Journal of Clinical Child and Adolescent Psychology, 31,* 123-129. doi: 10.1207/S15374424JCCP3101_14

Castellanos, F. X., Sonuga-Barke, E. J. S., Milham, M. P., & Tannock, R. (2006). Characterizing cognition in ADHD: beyond executive dysfunction. *Trends in Cognitive Science, 10,* 117-123. doi: 10.1016/j.tics.2006.01.011

Combs, M. A., Canu, W. H., Broman-Fulks, J., & Nieman, D. C. (2014). Impact of sluggish cognitive tempo and attention-deficit/hyperactivity disorder symptoms on adults' quality of life. *Applied Research in Quality of Life*, *9*, 981-995. doi: 10.1007/s11482-013-9281-3

Corbett, B. A., Constantine, L. J., Hendren, R., Rocke, D., & Ozonoff, S. (2009). Examining executive functioning in children with autism spectrum disorder, attention deficit hyperactivity disorder and typical development. *Psychiatry Research, 166,* 210-222. doi: 10.1016/j.psychres.2008.02.005

Diamond, A. (2012). Activities and programs that improve children's executive functions. *Current Directions in Psychological Science, 21,* 335-341. doi: 10.1177/0963721412453722

Diamond, A. (2005). Attention-deficit disorder (attention-deficit/hyperactivity disorder without hyperactivity): A neurobiologically and behaviorally distinct disorder from attention-deficit/hyperactivity disorder (with hyperactivity). *Development and Psychopathology*, *17*, 807–825. doi: 10.1017/S0954579405050388

Di Giovinazzo, V. & Novarese, M. (2016). The meaning of happiness: attention and time perception. *Mind & Society, 15,* 207-218. doi: 10.1007/s11299-015-0180-1

Fassbender, C., Krafft, C. E., & Schweitzer, J. B. (2015). Differentiating SCT and inattentive symptoms in ADHD using fMRI measures of cognitive control. *Neuroimage: Clinical, 8,* 390-397. doi: 10.1016/j.nicl.2015.05.007

Field, A. (2013). Discovering statistics using IBM SPSS statistics. London, England: SAGE.

Flannery, A. J., Luebbe, A. M., & Becker, S. P. (2016). Sluggish cognitive tempo is associated with poorer study skills, more executive functioning deficits, and greater impairment in college students. *Journal of Clinical Psychology, 9,* 1091-1113. doi: 10.1002/jclp.22406

Flannery, A. J., Becker, S. P., & Luebbe, A. M. (2016). Does emotion dysregulation mediate the association between sluggish cognitive tempo and college students' social impairment? *Journal of Attention Disorders*, *20*, 802-812. doi:10.1177/1087054714527794

Franklin, M. S., Mrazek, M. D., Anderson, C. L., Johnson, C., Smallwood, J. Kingstone, A., & Schooler, J. W. (2014). Tracking distraction: the relationship between mind-wandering, meta-awareness, and ADHD symptomology. *Journal of Attention Disorders*, 21, 475-486. doi: 10.1177/1087054714543494

Fontes, R., Ribeiro, J., Gupta, D. S., Machado, D., Lopes-Junior, F., Bastos, V. H., … Teixeira, S. (2016). Time perception mechanisms at central nervous system. *Neurology International, 8,* 14-22. doi: 10.4081/ni.2016.5939

Foster, S. M., Kisley, M. A., Davis, H. P., Diede, N. T., Campbell, A. M., & Davalos, D. B. (2013). Cognitive function predicts neural activity associated with pre-attentive temporal processing. *Neuropsychologia, 2,* 211-219. doi: 10.1016/j.neuropsychologia.2012.09.017

Garner, A. A., Marceaus, J. C., Mrug, S., Patterson, C., & Hodgens, B. (2010). Dimensions and correlates of attention deficit/hyperactivity disorder and sluggish cognitive tempo. *Journal of Abnormal Child Psychology, 38*, 1097-1107. doi: 10.1007/s10802-010-9436-8

Gerrig, R.J., & Zimbardo, P. G. (2002). Psychology and life ($16^{th}$ ed.). Boston, MA: Allyn & Bacon.

Grondin, S. (2010). Timing and time perception: A review of recent behavioral and neuroscience findings and theoretical directions. *Attention, Perception, & Psychophysics, 72*, 561-582. doi: 10.3758/APP.72.3.561

Geurts, H. M., Verte, S., Oosterlaan, J., Roeyers, H., & Sergeant, J. A. (2004). How specific are executive functioning deficits in attention deficit hyperactivity disorder and autism? *The Journal of Child Psychology and Psychiatry, 45*, 836-854. doi: 10.1111/j.1469-7610.2004.00276.x

IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.

Jarrett, M. A., Rapport, H. F., Rondon, A. T., & Becker, S. P. (2017). ADHD dimensions and sluggish cognitive tempo symptoms in relation to self-report and laboratory measures of neuropsychological functioning in college students. *Journal of Attention Disorders, 21,* 673-683. doi: 10.1177/1087054714560821

Kail, R., & Salthouse, T. A. (1994). Processing speed as a mental capacity. *Acta Psychologica, 86,* 199-225. doi: 10.1016/0001-6918(94)90003-5

Kam, J. W. Y., & Handy, T. C. (2014). Differential recruitment of executive resources during mind wandering. *Consciousness and Cognition, 26,* 51-63. doi: 10.1016/j.concog.2014.03.002

Kane, M. J., Brown, L. H., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when: An experience-sampling of working memory and executive control in daily life. *Association for Psychological Science, 18,* 614-621. doi: 10.1111/j.1467-9280.2007.01948.x

Khadka, G., Burns, G. L, & Becker, S. P. (2015). Internal and external validity of sluggish cognitive tempo and ADHD inattention dimensions with teacher ratings of Nepali children. *Journal of Psychopathology and Behavioral Assessment, 38,* 433-442. doi: 10.1007/s10862-015-9534-6

Lahey, B. B., Schaughency, E., Strauss, C., & Frame, C. (1984). Are attention deficit disorders with and without hyperactivity similar or dissimilar disorders? *Journal of the American Academy of Child Psychiatry*, *23*, 302–309. doi: 10.1016/S0002-7138(09)60508-2

Lahey, B. B., Schaughency, E. A., Frame, C. L., & Strauss, C. C. (1985). Teacher ratings of attention problems in children experimentally classifies as exhibiting attention deficit disorder with and without hyperactivity. *Journal of the American Academy of Child Psychology, 24,* 613-616. doi: 10.1016/S0002-7138(09)60064-9

Lahey, B. B., Schaughency, E., Hynd, G., Carlson, C., & Niever, C. (1987). Attention deficit disorder with and without hyperactivity: Comparison of behavioral characteristics of clinic referred children. *Journal of the American Academy of Child Psychology, 23,* 718-723. doi: 10.1097/00004583-198709000-00017

Langberg, J. M., Becker, S. P., Dvorsky, M. R., & Luebbe, A. M. (2014). Are sluggish cognitive tempo and daytime sleepiness distinct constructs? *Psychological Assessment, 26,* 586-597. doi: 10.1037/a0036276

Lee, S., Burns, G. L., Snell, J., & McBurnett, K. (2014). Validity of the sluggish cognitive tempo symptom dimension in children: Sluggish cognitive tempo and ADHD-inattention as district symptom dimensions. *Journal of Abnormal Child Psychology, 42,* 7-19. doi: 10.1007/s10802-013-9714-3

Lee, S., Burns, G. L., Beauchaine, T., & Becker, S. (2016). Bifactor latent structure of attention-deficit/hyperactivity disorder (ADHD)/oppositional defiant disorder (ODD) symptoms and first-order latent structure of sluggish cognitive tempo symptoms. *Psychological Assessment, 28,* 917-928. doi: 10.1037/pas0000232

Leikauf, J. E. & Solanto, M. V. (2016). Sluggish cognitive tempo, internalizing symptoms, and executive functions in adults with ADHD. *Journal of Attention Disorders, 21,* 701-711. doi: 0.1177/1087054716659361

Maniadakis, M., & Trahanias, P. (2011). Temporal cognition: A key ingredient of intelligent systems. *Frontiers in Neurorobotics*, *5,* 1-6. doi: 10.3389/fnbot.2011.00002

Matthews, W. J., & Meck, W. H. (2016). Temporal cognition: Connecting subjective time to perception, attention, and memory. *Psychological Bulletin*, *142*, 865-907. doi: 10.1037/bul0000045

McBurnett, K., Villodas, M., Burns, G. L., Hinshaw, S. P., Beaulieu, A., & Pfiffner, L. J. (2014). Structure and validity of sluggish cognitive tempo using an expanded item pool in children with attention-deficit/hyperactivity disorder. *Journal of Abnormal Psychology, 42,* 37-48. doi: 10.1007/s10802-013-9801-5

McVay, J. C., & Kane, M. J. (2010). Does mind wandering reflect executive function or executive failure? Comment on Smallwood and Schooler (2006) and Watkins (2008). *Psychological Bulletin*, *136*, 188–207. doi: 10.1037/a0018298

McVay, J.C., & Kane, M. J. (2012). Why does working memory capacity predict variation in reading comprehension? On the influence of mind wandering and executive attention. *Journal of Experimental Psychology, 141,* 302-320. doi: 10.1037/a0025250

Milich, R., Ballentine, A. C., & Lynam, D.R. (2001). ADHD/combined type and ADHD/predominantly inattentive type are distinct and unrelated disorders. *Clinical Psychology: Science and Practice, 8,* 463-488. doi: 10.1093/clipsy.8.4.463

Moll, K., Göbel, S. M., Gooch, D., Landerl, K., & Snowling, M. J. (2016). Cognitive risk factors for specific learning disorder: Processing speed, temporal processing, and working memory. *Journal of Learning Disabilities, 49,* 272-281. doi: 10.1177/0022219414547221

Pachai, A. A., Acai, A., LoGiudice, A. B., & Kim, J. A. (2016). The mind that wanders: Challenges and potential benefits of mind wandering in education. *Scholarship of Teaching and Learning in Psychology, 2,* 134-146. doi: 10.1037/stl0000060

Prevatt, F., Proctor, B., Baker, L., Garrett, L., & Yelland, S. (2011). Time estimation abilities of college students with ADHD. *Journal of Attention Disorders, 15,* 531-538. doi: 10.1177/1087054710370673

Radonovich, K. J., & Mostofsky, S. H. (2004). Duration judgments in children with ADHD suggest deficient utilization of temporal information rather than general impairment in timing. *Child Neuropsychology, 10,* 162-172. doi: 10.1080/09297040409609807

Raichle, M. E. (2015). The brain's default mode network. *Annual Review of Neuroscience, 38,* 433-447. doi: 10.1146/annurev-neuro-071013-014030

Sattler, J. M., & Ryan, J. J. (2009). *Assessment with the WAIS-IV*. San Diego, Calif: Jerome M. Sattler.

Schooler, J. W., Mrazek, M. D., Frankin, M.S., Baird, B., Mooneyham, B. W., Zedelius, C. Broadway, J. M. (2014). Chapter One – The Middle Way: Finding the balance between mindfulness and mind-wandering. *Psychology of Learning and Motivation, 60,* 1-33. doi: 10.1016/B978-0-12-800090-8.00001-9

Schooler, J. W., Smallwood, J., Christoff, K., Handy, T. C., Reichle, E. D., & Sayette, M. A. (2011). Meta-awareness, perceptual decoupling and the wandering mind. *Trends in Cognitive Sciences, 15,* 319-326. doi: 10.1016/j.tics.2011.05.006

Sibley, M. H., Pelham, W. E., Molina, S. G., Gnagy, E. M., Waxmonsky, J. G. Waschbusch, D. A., …Kuriyan, A. B. (2012). When diagnosing ADHD in young adults emphasize informant reports, DSM items, and impairment. Journal of Counseling and Clinical Psychology, 80, 1052-1061. doi:10.1037/a0022172

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin, 132,* 946-958. doi: 10.1037/0033-2909.132.6.946

Smallwood, J., & Schooler, J.W. (2015). The science of mind wandering: Empirically navigating the stream of consciousness. *Annual Review of Psychology, 66,* 487-518. doi: 10.1146/annurev-psych-010814-015331

Smith, Z. R., Eadeh, H., Breaux, R. P., & Langberg, J. M. (2019). Sleep, sluggish, worried, or down? The distinction between reported sluggish cognitive tempo daytime sleepiness, and internalizing symptoms in youth with attention-deficit/hyperactivity disorder. *American Psychological Association, 31,* 365-375. doi: 10.1037/pas0000671

Sorrell, A., & Canu, W. H. (2018). Sluggish Cognitive Tempo and temporal processing: An exploratory examination of association using a novel measure. *The ADHD Report, 26,* 7-12. doi: 10.1521/adhd.2018.26.7.7

Stuss, D. T., & Alexander, M. P. (2000). Executive functions and the frontal lobes: a conceptual view. *Psychological Research, 63,* 289-298. doi: 10.1007/s004269900007

Tamm, L., Brenner, S. B., Bamberger, M. E., Becker, S. P. (2016). Are sluggish cognitive tempo symptoms associated with executive functioning in preschoolers? *Child Neuropsychology, 24,* 82-105. doi: 10.1080/09297049.2016.1225707

Tamm, L., Garner, A. A., Loren, R. E, Epstein, J. N., Vaughn, A. J., Ciesielski, H. A., & Becker, S. P. (2016). Slow sluggish cognitive tempo symptoms are associated with poorer academic performance in children with ADHD. *Psychiatry Research*, *242,* 251-259. doi: 10.1016/j.psychres.2016.05.054

Toplak, M. E., Rucklidge, J. J., Hetherington, R., John, S. C. F., & Tannock, R. (2003). Time perception deficits in attention-deficit/ hyperactivity disorder and comorbid reading difficulties in child and adolescent samples. *Journal of Child Psychology and Psychiatry, 44,* 888–903. doi:10.1111/1469-7610.00173

Valko, L., Doehnert, M., Muller, U. C., Schneider, G., Albrecht, B., … Brandeis, D. (2009). Differences in neurophysiological markers of inhibitory and temporal processing deficits in children and adults with ADHD. *Journal of Psychophysiology, 23,* 235-236. doi: 10.1027/0269-8803.23.4.235

Wahlstedt, C. & Bohlin, G. (2010). DSM-IV-defined inattention and sluggish cognitive tempo: independent relations to neuropsychological factors and comorbidity. *Child Neuropsychology, 16, 350*-365. doi: 10.1080/09297041003671176

Willcutt, E. G., Chhabildas, N., Kinnear, M., DeFries, J. C., Olson, R. K., Leopold, D. R., & ... Pennington, B. F. (2014). The internal and external validity of sluggish cognitive tempo and its relation with DSM–IV ADHD. *Journal of Abnormal Child Psychology*, *42*, 21-35. doi: 10.1007/s10802-013-9800-6SCT

Wechsler, D. (2008). *Wechsler Adult Intelligence Scale—Fourth Edition*. San Antonio, TX: Pearson.

Wood, W. L., Lewandowski, L. J., Lovett, B. J., & Antshel, K. M. (2014). Executive dysfunction and functional impairment associated with sluggish cognitive tempo in emerging adulthood. *Journal of Attention Disorders*, *21,* 691-700. doi: 10.1177/1087054714560822

Zakay, D. (1990). The evasive art of subjective time measurement: Some methodological dilemmas. In R. A. Block (Ed.), *Cognitive Models of Psychological Time* (pp. 59-84). New Jersey: Lawrence Erlbaum Associates, Inc.

Zinke, K., Altgassen, M., Mackinlay, R. J., Rizzo, P., Drechsler, R., & Kliegel, M. (2010). Time-based prospective memory performance and time-monitoring in children with ADHD. *Child Neuropsychology, 16*, 338-349. doi: 10.1080/09297041003631451

## Notes

[1] Of note, Pearson correlations between ADHD symptom clusters (i.e., inattention, hyperactive, and impulsive) as measured from the BAARS-IV and SCT and outcome variables were conducted. Results showed that individual clusters were not substantially different than the ADHD total, and Total ADHD scores from the BAARS-IV were used in all models.

Table 1. Sample characteristics.

| | |
|---|---|
| Basic Demographics | |
| Age, $M \pm SD$ | 19.87 ± 1.75 |
| Years of education, $M \pm SD$ | 12.80 ± .96 |
| Caucasian, *n* (%) | 88 (90.7) |
| Female, *n* (%) | 64 (65.3) |
| Psychological History, % | |
| Academic problem | 7.1 |
| ADHD | 12.6 |
| Any anxiety disorder | 18.4 |
| Any depressive disorder | 15.3 |

*Notes.* Psychological history includes any lifetime history of diagnoses that participants endorsed on demographic and medical history form. Total *n* for response to ADHD diagnosis question = 95.

Table 2. Descriptive statistics for dependent and independent variables.

| | *n* | Mean | SD |
|---|---|---|---|
| Predictor Variables | | | |
| SCT (Z scores) | 98 | 0.00 | 0.96 |
| ACI | 98 | 15.51 | 7.74 |
| BAARS-IV SCT | 98 | 15.18 | 5.08 |
| BAARS-IV Total ADHD | 95 | 28.88 | 8.42 |
| Dependent Variables | | | |
| TES | 93 | 77.25 | 74.08 |
| TR | 85 | 70.98 | 95.06 |
| Prospective | 93 | 6.37 | 4.30 |
| Retrospective | 90 | 4.89 | 4.64 |
| In-Vivo | 97 | 35.42 | 24.21 |
| BDEFS-SMT | 92 | 37.11 | 12.10 |
| SCOTT | 94 | 51.79 | 12.31 |

*Notes.* For meaningful interpretation, means and standard deviations for TES, TR, Prospective, Retrospective, In-Vivo, and BDEFS- SMT reflect raw scores before logarithmic transformation. SCT = calculated z scores of ACI and BAARS-IV SCT measures. ACI = Adult Concentration Inventory total raw score; BAARS-IV SCT = Barkley Adult ADHD Scale, Fourth Edition, SCT domain total raw scores; BAARS-IV Total ADHD = total ADHD raw scores; TES = short-term time estimation task absolute discrepancy scores, in seconds; TR = time reproduction task absolute discrepancy scores, in seconds; Prospective = prospective estimate absolute discrepancy scores on long-term time estimation (i.e., document sorting) task, in minutes; Retrospective = retrospective estimate absolute discrepancy scores on long-term time estimation task, in minutes; In-Vivo = absolute discrepancy scores of all in-vivo time estimates, in minutes; BDEFS-SMT = raw scores from the Barkley Deficits in Executive Functioning Scale – Self-Management to Time domain; SCOTT = total raw scores from the Sorrell-Canu Orientation to Time measure.

Table 3. Descriptive statistics for the WAIS-IV.

| WAIS-IV Variables | Min | Max | Mean | *SD* |
|---|---|---|---|---|
| Estimated FSIQ | 85 | 130 | 104.86 | 9.39 |
| Figure Weights (PR) | 5 | 18 | 11.23 | 2.82 |
| Coding (PS) | 5 | 19 | 11.16 | 2.49 |
| Information (VC) | 5 | 17 | 11.1 | 2.60 |
| Digit Span (WM) | 5 | 17 | 9.53 | 2.30 |

*Notes.* WAIS-IV = Wechsler Adult Intelligence Scale 4th edition; FSIQ = full scale IQ; Estimated FSIQ calculated from four subtests, $n$ = 95; Figure Weights $n$ = 97; Coding $n$ = 96; $n$ = 97 for remaining subtests. WAIS-IV subtests are representative of the four standard WAIS-IV indices as represented in parentheses, corresponding to: PR = Perceptual Reasoning; PS = Processing Speed; VC = Verbal Comprehension subtest; WM = Working Memory subtest. Scores presented for WAIS subtests are standard scores.

Table 4. Pearson's correlations between WAIS-IV subtests and dependent variables.

| Dependent Variables | FSIQ | DS | IN | CD | FW |
|---|---|---|---|---|---|
| TES | .14 | -.09 | .04 | -.05 | -.01 |
| TR | -.18 | .05 | -.18 | -.11 | -.16 |
| Prospective | .08 | .13 | .02 | -.01 | .10 |
| Retrospective | -.02 | .04 | .06 | -.10 | -.08 |
| In-Vivo | -.01 | .09 | .08 | -.09 | .04 |
| BDEFS-SMT | .14 | .04 | **.31** ** | -.12 | .17 |
| SCOTT | -.00 | .04 | -.15 | .17 | -.02 |

*Notes.* FSIQ = Full Scale IQ derived from four-subtest short-form; DS = Digit Span; IN = Information; CD = Coding; FW = Figure Weights; TES = short-term time estimation task absolute discrepancy scores; TR = time reproduction task absolute discrepancy scores; Prospective = prospective estimate absolute discrepancy scores on long-term time estimation (i.e., document sorting) task; Retrospective = retrospective estimate absolute discrepancy scores on long-term time estimation task; In-Vivo = absolute discrepancy scores of all in-vivo time estimates; BDEFS-SMT = total raw scores from the Barkley Deficits in Executive Functioning Scale – Self-Management to Time domain; SCOTT = Sorrell-Canu Orientation to Time total raw scores. **= $p$ < .01.

Table 5. Pearson's correlations between mean SCT score and dependent variables.

| Dependent variable | *r* with SCT | *n* |
|---|---|---|
| TES | 0.18 | 93 |
| TR | 0.09 | 85 |
| Prospective | 0.16 | 93 |
| Retrospective | 0.07 | 90 |
| In-vivo | 0.12 | 97 |
| BDEFS-SMT | **0.76**** | 92 |
| SCOTT | **-0.57**** | 94 |

*Notes.* TES = short-term time estimation task absolute discrepancy scores; TR = time reproduction task absolute discrepancy scores; Prospective = prospective estimate absolute discrepancy scores on long-term time estimation (i.e., document sorting) task; Retrospective = retrospective estimate absolute discrepancy scores on long-term time estimation task; In-Vivo = absolute discrepancy scores of all in-vivo time estimates; BDEFS-SMT = total raw scores for the Barkley Deficits in Executive Functioning Scale – Self-Management to Time domain; SCOTT = total raw scores for the Sorrell-Canu Orientation to Time measure. **= $p < .01$.

Table 6. Pearson's correlations between BAARS-IV ADHD domains and dependent variables.

| Dependent Variables | | Impulsive | Hyperactive | Inattention | Total ADHD |
|---|---|---|---|---|---|
| TES | | | | | |
| | *r* | 0.06 | 0.04 | 0.20 | 0.14 |
| | *n* | 93 | 92 | 91 | 90 |
| TR | | | | | |
| | *r* | 0.06 | -0.05 | 0.13 | 0.07 |
| | *n* | 85 | 84 | 83 | 82 |
| Prospective | | | | | |
| | *r* | 0.00 | 0.01 | 0.06 | 0.04 |
| | *n* | 93 | 92 | 91 | 90 |
| Retrospective | | | | | |
| | *r* | 0.15 | -0.02 | -0.04 | 0.01 |
| | *n* | 90 | 89 | 88 | 87 |
| In-Vivo | | | | | |
| | *r* | -0.04 | 0.03 | 0.11 | 0.06 |
| | *n* | 97 | 97 | 95 | 95 |
| BDEFS-SMT | | | | | |
| | *r* | **.41**** | **.37**** | **.75**** | **.69**** |
| | *n* | 92 | 91 | 91 | 90 |
| SCOTT | | | | | |
| | *r* | **-.37**** | **-.25*** | **-.56**** | **-.52**** |
| | *n* | 94 | 93 | 92 | 91 |

Notes. TES = Time Estimation short-term task absolute discrepancy scores; TR = Time Reproduction task absolute discrepancy scores; Prospective = Prospective estimate absolute discrepancy scores on long-term time estimation (i.e., document sorting) task; Retrospective = Retrospective estimate absolute discrepancy scores on long-term time estimation task; In-Vivo = absolute discrepancy scores of all in-vivo time estimates; BDEFS-SMT = Barkley Deficits in Executive Functioning Scale – Self-Management to Time domain total raw scores; SCOTT = Sorrell-Canu Orientation to Time total raw scores. **= $p < .01$. *= $p < .05$.

Table 7. Results of multiple regression analyses for models one and two.

| Predictor Variables | | *t* | *p* | ß | *F* | *df* | *p* | $R^2$ |
|---|---|---|---|---|---|---|---|---|
| TES | Overall model | | | | 1.54 | 2, 87 | .22 | .03 |
| | SCT | 1.14 | 0.26 | .19 | | | | |
| | ADHD | -.03 | 0.98 | -.01 | | | | |
| TR | Overall model | | | | .28 | 2,79 | .76 | .01 |
| | SCT | .39 | .70 | .07 | | | | |
| | ADHD | .14 | .89 | .02 | | | | |

*Notes.* ß values reported are standardized ß. $R^2$ values are unadjusted. TES = short-term time estimation task absolute discrepancy scores. TR = time reproduction task absolute discrepancy scores.

Table 8. Results of multiple regression analyses for models three, four, and five.

| Predictor Variables | | *t* | *p* | ß | *F* | *df* | *p* | $R^2$ |
|---|---|---|---|---|---|---|---|---|
| Prospective | Overall model | | | | 2.20 | 2,87 | .12 | .05 |
| | SCT | 2.07 | .04 | .34 | | | | |
| | ADHD | -1.36 | .18 | -.22 | | | | |
| Retrospective | Overall model | | | | .14 | 2.84 | .87 | .01 |
| | SCT | .52 | .61 | .09 | | | | |
| | ADHD | -.34 | .74 | .06 | | | | |
| In-Vivo | Overall model | | | | 1.02 | 2.92 | .37 | .02 |
| | SCT | 1.31 | .19 | .21 | | | | |
| | ADHD | -.66 | .51 | -.11 | | | | |

*Notes*. ß values reported are standardized ß. $R^2$ values are unadjusted. Prospective = prospective estimate absolute discrepancy scores on long-term time estimation (i.e., document sorting) task; Retrospective = retrospective estimate absolute discrepancy scores on long-term time estimation task; In-Vivo = absolute discrepancy scores of all in-vivo time estimates.

Table 9. Results of multiple regression analyses for models six and seven.

| Predictor Variables | | *t* | *p* | ß | *F* | *df* | *p* | $R^2$ |
|---|---|---|---|---|---|---|---|---|
| BDEFS-SMT | Overall model | | | | 64.20 | 2, 87 | .00 | .60 |
| | SCT | 5.23 | 0.00 | .57 | | | | |
| | ADHD | 2.15 | 0.00 | .24 | | | | |
| SCOTT | Overall model | | | | 22.82 | 2,88 | .00 | .33 |
| | SCT | -3.18 | .00 | -.44 | | | | |
| | ADHD | -1.28 | .21 | -.18 | | | | |

*Notes.* ß values reported are standardized ß. $R^2$ values are unadjusted. BDEFS-SMT = total raw scores for th Barkley Deficits in Executive Functioning Scale – Self-Management to Time domain; SCOTT = total raw scores for the Sorrell-Canu Orientation to Time measure.

Appendix A

**From:** IRB <irb@appstate.edu>
**Date:** September 13, 2018 at 3:56:02 PM EDT
**To:** <canuwh@appstate.edu>, <sorrellae@appstate.edu>
**Subject: IRB Notice - 18-0040**

**To:** Anne Sorrell
Psychology
CAMPUS EMAIL

**From:** Dr. Andrew Shanely, IRB Chairperson
**Date:**
**RE:** Notice of IRB Approval by Expedited Review (under 45 CFR 46.110)
**Agrants #**:
**Grant Title**:

**STUDY #:** 18-0040
**STUDY TITLE:** Temporal Processing and Sluggish Cognitive Tempo in College Students
**Submission Type:** Modification
**Expedited Category:** (7) Research on Group Characteristics or Behavior, or Surveys, Interviews, etc.,Minor Change to Previously Approved Research
**Approval Date:** 9/13/2018
**Expiration Date of Approval:** 1/02/2019

The Institutional Review Board (IRB) approved the modification for this study. The IRB found that the research procedures meet the expedited category cited above. IRB approval is limited to the activities described in the IRB approved materials, and extends to the performance of the described activities in the sites identified in the IRB application. In accordance with this approval, IRB findings and approval conditions for the conduct of this research are listed below.

**Submission Description:**

I intend on collecting and storing research study data on the HIPAA-approved, secure data entry system, REDCap.

**Study Regulatory and other findings:**

The IRB determined that this study involves minimal risk to participants.

All approved documents for this study, including consent forms, can be accessed by logging into IRBIS. Use the following directions to access approved study documents.

1. Log into IRBIS
2. Click "Home" on the top toolbar

3. Click "My Studies" under the heading "All My Studies"
4. Click on the IRB number for the study you wish to access
5. Click on the reference ID for your submission
6. Click "Attachments" on the left-hand side toolbar
7. Click on the appropriate documents you wish to download

**Approval Conditions:**

Appalachian State University Policies: All individuals engaged in research with human participants are responsible for compliance with the University policies and procedures, and IRB determinations.

Principal Investigator Responsibilities: The PI should review the IRB's list of PI responsibilities. The Principal Investigator (PI), or Faculty Advisor if the PI is a student, is ultimately responsible for ensuring the protection of research participants; conducting sound ethical research that complies with federal regulations, University policy and procedures; and maintaining study records.

Modifications and Addendums: IRB approval must be sought and obtained for any proposed modification or addendum (e.g., a change in procedure, personnel, study location, study instruments) to the IRB approved protocol, and informed consent form before changes may be implemented, unless changes are necessary to eliminate apparent immediate hazards to participants. Changes to eliminate apparent immediate hazards must be reported promptly to the IRB.

Approval Expiration and Continuing Review: The PI is responsible for requesting continuing review in a timely manner and receiving continuing approval for the duration of the research with human participants. Lapses in approval should be avoided to protect the welfare of enrolled participants. If approval expires, all research activities with human participants must cease.

Prompt Reporting of Events: Unanticipated Problems involving risks to participants or others; serious or continuing noncompliance with IRB requirements and determinations; and suspension or termination of IRB approval by external entity, must be promptly reported to the IRB.

Closing a study: When research procedures with human subjects are completed, please log into our system a https://appstate.myresearchonline.org/irb/index_auth.cfm and complete the Request for Closure of IRB review form.

**Websites:**

1. PI
responsibilities: http://researchprotections.appstate.edu/sites/researchprotections.appstate.edu

/files/PI%20Responsibilities.pdf

2. IRB forms: http://researchprotections.appstate.edu/human-subjects/irb-forms

CC:
Will Canu, Psychology
Appendix B

Appendix B

**Consent to Participate in Research**
*Information to Consider About this Research*

***Temporal Processing and Sluggish Cognitive Tempo in College Students***

**Principal Investigator:** Anne Sorrell, B.S.
**Department:** Psychology
**Contact Information:** You may e-mail me directly at sorrellae@appstate.edu or you may call Dr. Will Canu at 828-262-2272 ext. 412

You are being invited to take part in a research study about temporal (time) processing abilities in college-aged adults who do and do not endorse behaviors that constitute a new cluster of symptoms termed Sluggish Cognitive Tempo (SCT). Sluggish Cognitive Tempo (SCT) is characterized by a set of behaviors such as feeling sleepy or lethargic, having a tendency to daydream excessively, having trouble staying awake and alert, staring a lot, feeling mentally "foggy" or confused, seeming slow-moving or sluggish, and appearing to process information slowly. These behaviors were previously conceptualized in the scientific literature as a cluster of symptoms related to the inattentiveness (IA) subtype of attention-deficit/hyperactivity disorder (ADHD). Recent evidence, however, has demonstrated that SCT is indeed a distinct construct independent of, but often comorbid with, ADHD-IA. Still, findings regarding the neuropsychological nature of SCT are rather limited, particularly in comparison to ADHD.

If you take part in this study, you will be one of about 100 people to do so. By doing this study we hope to learn what temporal (time) processing abilities, if any, are impacted by SCT and/or Attention-Deficit/Hyperactivity Disorder (AD/HD).

The research procedures will be conducted at Appalachian State University in Smith-Wright Hall (physical address: 222 Joyce Lawrence Lane), Room 201 ($2^{nd}$ floor).

There are many medications, diseases, and medical conditions which can affect a person's performance on study-related tasks. Therefore, you will be asked to answer questions about your medical history. By looking at the medical survey, we can note any potential factors that may affect the task performance.

You will also be asked to complete several paper-and-pencil surveys and questionnaires. These questions are directly related to the topic we are studying. Furthermore, you will be required to participate in a brief measure of your cognitive abilities (referred to as neuropsychological testing) for study purposes. No preparation is required before you undergo the assessment. Lastly, we will ask you to complete several activities intended to measure your time estimation and reproduction abilities. We expect total time for the study visit to be approximately 1.5 hours.

*You cannot volunteer for this study if are under 18 years of age.*

**What are possible harms or discomforts that I might experience during the research?**

To the best of our knowledge, the risk of harm for participating in this research study is no more than you would experience in everyday life.

Neuropsychological testing can sometimes result in some feelings of nervousness or frustration. However, you will be encouraged to take as many breaks as you need during the testing session, and you may discontinue testing at any point you choose during the assessment.

**What are the possible benefits of this research?**

There may be no personal benefit from your participation but the information gained by doing this research may help others in the future by adding to the growing field of research on sluggish cognitive tempo (SCT).

You will not be paid for your participation in this study. However, you can earn up to 3 ELC credits for your participation. There are other research options and non-research options for obtaining extra credit or ELC's. One non-research option to receive 1 ELC is to read an article and write a 1-2 page paper summarizing the article and your reaction to the article. More information about this option can be found at: psych.appstate.edu/research. You may also wish to consult your professor to see if other non-research options are available.

**Will I be paid for taking part in the research?**

We will not pay you for the time you volunteer while being in this study.

**How will you keep my private information confidential?**

We will make every effort to prevent anyone who is not on the research team knowing that you gave us information or what that information is. To assure confidentiality, any indication of your name or personal information will be removed from study documents, and a code will be assigned in its place. Your name will not appear on any study documents, or in papers or presentations resulting from this research. Furthermore, all study documentation will be coded and entered into a secure database. Your data will be protected under the full extent of the law.

**Who can I contact if I have questions?**

The people conducting this study will be available to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator, Anne Sorrell, via e-mail at sorrellae@appstate.edu. In most cases, e-mails will be returned within several hours. You may also directly contact the Faculty Advisor for this study, Dr. Will Canu, at 828-262-2272 extension 412.

If you have questions about your rights as someone taking part in research, contact the Appalachian Institutional Review Board Administrator at 828-262-2692 (days), through email at irb@appstate.edu or at Appalachian State University, Office of Research and Sponsored Programs, IRB Administrator, Boone, NC 28608.

**Do I have to participate? What else should I know?**

Your participation in this research is completely voluntary. If you choose not to volunteer, there will be no penalty and you will not lose any benefits or rights you would normally have. If you decide to take part in the study you still have the right to decide at any time that you no longer want to continue. There will be no penalty and no loss of benefits or rights if you decide at any time to stop participating in the study. If you decide to participate in this study, let the research personnel know. A copy of this consent form is yours to keep.

This research project has been approved by the Institutional Review Board (IRB) at Appalachian State University.

This study was approved on:

This approval will expire on __________ unless the IRB renews the approval of this research.

_______________________________________________________________

Participant's Name (PRINT) Signature Date

Appendix C

**DEMOGRAPHICS & MEDICAL SCREENING FORM**

Study ID: _________
Screener Initials: _________
Date Completed: ___________

Temporal Processing and Sluggish Cognitive Tempo in College Students

**I. DEMOGRAPHICS**

**Birth Date (MM/DD/YYYY):** _____________ **Age:** _______ years

**Year in school (circle one):** Freshman Sophomore Junior Senior Graduate Other: __________

**Height**: _______ feet ________ inches **Weight:** ___________ pounds

**Sex:**
- ☐ Female
- ☐ Male
- ☐ Transgender
- ☐ Unspecified

**Handedness:**
- ☐ Right
- ☐ Left
- ☐ Ambidextrous (neither hand is dominant)

**Race:**
- ☐ American Indian/Alaska Native
- ☐ Asian
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ Black or African American
- ☐ White or Caucasian/European American
- ☐ Multi-racial
- ☐ Unknown or other: ______________

**Ethnicity:**
- ☐ Hispanic/Latino
- ☐ NOT Hispanic/Latino

**Is English the first/primary language?**
- ☐ Yes
- ☐ No. If not, what is the first/primary language? ____________________________________________

**14. Parents' Highest Completed Level of Education:**

**Mother**
- ☐ Less than 12th grade
- ☐ High School graduate
- ☐ GED or equivalent
- ☐ Some college, no degree
- ☐ Associate's Degree
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Doctoral Degree
- ☐ Unknown

**Father**
- ☐ Less than 12th grade
- ☐ High School graduate
- ☐ GED or equivalent
- ☐ Some college, no degree
- ☐ Associate's Degree
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Doctoral Degree
- ☐ Unknown

## II. MEDICAL HISTORY (note current/past)

**Have you ever been diagnosed with any of the following?**

| | No | Yes | If yes, what year? |
|---|---|---|---|
| Academic problems | | | |
| Allergies | | | |
| Asthma | | | |
| Anxiety disorder | | | |
| Autoimmune disease (e.g., MS, lupus) | | | |
| Cancer (e.g., breast cancer, brain tumor) | | | |
| Developmental disorder | | | |
| Depression | | | |
| Diabetes | | | |
| Drug or alcohol abuse/dependence | | | |
| Head injury or concussion | | | |
| Hearing loss | | | |
| Learning disorder (reading, writing, math, other) | | | |
| Migraine or chronic headaches | | | |
| Musculoskeletal problems | | | |
| Other psychological/psychiatric disorder | | | |
| Seizures or epilepsy | | | |
| Sick-cell anemia | | | |
| Sleep disorder (e.g., insomnia, sleep apnea) | | | |
| Stroke | | | |
| Thyroid disease | | | |
| Vision Problems | | | |
| Other: | | | |
| | | | |
| | | | |
| | | | |

**Habits**

**Tobacco Use**: □ Currently use tobacco products. □ I used to use tobacco products, but now I do not. □ Never used tobacco products.

Age Started: ________
Age Stopped: ________

**Type(s) of tobacco used (choose all that apply):**
□ Cigars □Pipes □Chewing tobacco □Other
□ Cigarettes (average # per day _______)

☐ Alcohol use (note average quantity and frequency):

☐ Drugs (note type, average quantity, and frequency):

**Sleep**
On average, how many hours of sleep do you get per night? _____

On average, how many hours of sleep did you get last night? ______

**Below, please list all prescription medications, over-the-counter medications, herbal and/or vitamin supplements that you have been taking over the last 12 months:**

| Medication Name | Dose | Frequency | Route | Date Began | Indication/Purpose |
|---|---|---|---|---|---|
| *e.g., Medication* | *20mg* | *2x/day* | *Oral* | *09/07/2007* | *Diabetes* |

| III. DIAGNOSED ADHD PARTICIPANTS ONLY |
|---|

**20. What age (grade) ADHD diagnosed?**

☐ < 4 years (not in school): ______________________
☐ 4-5 years (pre-school)
☐ 5-6 years (kindergarten)
☐ 6-7 years (1st grade)
☐ 7-8 years (2nd grade)
☐ 8-9 years (3rd grade)
☐ 9-10 years (4th grade)
☐ 10-11 years (5th grade)
☐ 11-12 years (6th grade)
☐ 12-13 years (7th grade)
☐ 13+ years (> 7th grade): ________________________

**21. Any comorbid/co-existing diagnosis (note official/suspected)?**

☐ Externalizing disorders (e.g., conduct, oppositional defiant disorder): ________________________
☐ Internalizing disorder (e.g., anxiety, depression, obsessive compulsive disorder): ______________
☐ Learning disorders (e.g., verbal, non-verbal, dyslexia): _____________________________________
☐ Other: ________________________________________________________________________________
☐ None

**22. Do any family members have an ADHD diagnosis (current/past)?**

☐ Father: ______________________________________________________________________________
☐ Mother: ______________________________________________________________________________
☐ Sibling(s): ____________________________________________________________________________
☐ Grandparent(s): _______________________________________________________________________
☐ Aunt/Uncle: ___________________________________________________________________________
☐ Cousin(s): ____________________________________________________________________________
☐ Other:_______________________________________________________________________________
☐ Unknown
☐ None

| IV. Current Status |
|---|

**How many alcoholic drinks have you had in the last 24 hours?**

*Circle one:* None Some. List amount here:

**Are you currently sleep-deprived or physically exhausted?**

*Circle one:* No Yes If Yes, please explain:

# Appendix D

## **Chart Checklist & Record Sheet**

**Participant Study Appointment Time: ______: _______ AM / PM**

**Participant Arrival Time: ______: ______ AM / PM**

**Time Begin Appointment: ______: _______ AM / PM**

_____ Signed ICF

_____ Removal of time-telling devices

_____ Begin In-Vivo Stopwatch **Time: ______: _______ AM / PM**

_____ Dem/Med Form

_____ ACI

_____ BAARS

_____ B-DEFS

_____ DASS-21

_____ SCOTT

_____ ZPTI

_____ In-Vivo Estimate #1 **Time: ______: _______ AM / PM**

*"How long, in minutes, do you believe you have participated in study thus far?"*

**________ minutes, estimated** **________ minutes, actual**

_____ WAIS (5 subtests)

_____ In-Vivo Estimate #2 **Time: ______: _______ AM / PM**

**________ minutes, estimated** **________ minutes, actual**

_____ Time-estimation task, short term

_____ Time reproduction

_____ Time estimation, long term (document sorting)

_____ In-Vivo Estimate #3 **Time: ______: _______ AM / PM**

**________ minutes, estimated** **________ minutes, actual**

[End study visit.]

# Appendix E

## **Sorrell-Canu Orientation to Time Measure**

Directions: Read each item and check the appropriate answer according to the scale below:

| | VERY UNTRUE | UNTRUE | NEUTRAL | TRUE | VERY TRUE |
|---|---|---|---|---|---|
| 1. I am often late to appointments. | | | | | |
| 2. I always meet deadlines on time. | | | | | |
| 3. When I have a deadline for work or school, I allow myself enough time to work on the project. | | | | | |
| 4. I always allow enough time to make it to appointments. | | | | | |
| 5. I am able to estimate what time of day it is without looking at a clock. | | | | | |
| 6. I have difficulty estimating how much time it will take me to complete a task. | | | | | |
| 7. When I am doing something I enjoy, I tend to lose track of time. | | | | | |
| 8. When I get started on an assignment for work or school, I end up spending more time than I had planned. | | | | | |
| 9. If I don't use a timer or calendar alerts while working on a task, I will lose track of time. | | | | | |
| 10. I never have enough time to do things I enjoy. | | | | | |
| 11. I usually have an accurate idea of what time it is. | | | | | |
| 12. When taking a timed test, I am able to pace myself so that I have enough time to complete the test in its entirety. | | | | | |
| 13. I underestimate the time required to complete a task. | | | | | |
| 14. If I were to take a 30-minute lunch break with no watch, I am certain I would make it back to my desk on time. | | | | | |
| 15. Events scheduled a month in advance often arrive sooner than I anticipated. | | | | | |

| | VERY UNTRUE | UNTRUE | NEUTRAL | TRUE | VERY TRUE |
|---|---|---|---|---|---|
| 16. I am rarely ready to leave on time. | | | | | |
| 17. I like verbal reminders indicating how much time is remaining when I am taking a timed test. | | | | | |
| 18. I struggle to remember the dates events happened. | | | | | |
| 19. I often find myself pressed for time. | | | | | |
| 20. I am always early for appointments. | | | | | |
| 21. Being on time is important to me. | | | | | |
| 22. Without looking at my clock, I know how much time is left on my parking meter. | | | | | |
| 23. I am able to accurately estimate the length of a movie I have watched. | | | | | |

**Vita**

Anne Elizabeth Sorrell was born in Charleston, South Carolina, to John and Judy Sorrell. She has two older brothers, one older sister, and a total of seven nieces and nephews. Ms. Sorrell graduated from the College of Charleston in May 2014 with a Bachelor of Science degree in Psychology and a Minor in Religious Studies. Following graduation, she obtained a full time position as a Research Specialist working for Dr. Andreana Benitez, a licensed clinical neuropsychologist at the Medical University of South Carolina. In August 2016, Ms. Sorrell began a course of study toward a Master of Arts degree in Clinical Psychology at Appalachian State University. Ms. Sorrell will begin doctoral studies in Clinical Health Psychology at East Carolina University beginning Fall 2019.